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RELATION OF MINIMUM MOISTURE CONTENT OF SUBSOIL OF PRAIRIES TO HYGROSCOPIC COEFFICIENT[1]

F. J. Alway, G. R. McDole, and R. S. Trumbull

Introduction

It has long been recognized that the maxima and minima percentages of water found in well drained soils in the field are in general roughly dependent upon the relative fineness of texture, but very few data have been published in such form as to permit of any attempt to compute the actual relations which these extremes bear to the physical constants. In a previous paper (3) we have reported laboratory experiments and field observations showing that when loams, after rains sufficiently heavy to moisten them thoroughly, are protected from losses by evaporation and transpiration, they lose water by downward movement until the ratio of moisture content to hygroscopic coefficient reaches a value between 1.8 and about 2.5; while with coarse sands the ratio is as high as 6.0 or 7.0; and fine sands occupy an intermediate position, the ratio rising with a decrease in hygroscopicity.

While the maxima under field conditions are easily ascertainable anywhere, it being necessary only to await heavy rains or to irrigate a small area, the corresponding minima are developed only when a very scanty rainfall or a prolonged absence of precipitation is

[1] The work reported in this paper was carried out in 1907–1913, while the authors were members of the staff of the Nebraska Agricultural Experiment Station.

accompanied by weather conditions which stimulate both evaporation and transpiration, and so favor a reduction of the soil moisture content. These favoring conditions are high temperature, low atmospheric humidity, high wind velocity, and a high degree of insolation. Even in a semi-arid region several years may pass without the concurrence of the necessary conditions, while in humid regions such intervals are of still greater length.

The results of the greenhouse experiments of BRIGGS and SHANTZ (6) would suggest that after periods of extreme drought the prairie subsoil might be expected to show a moisture content which either approximated the so-called wilting coefficient (1.47 times the hygroscopic coefficient) or which was somewhat lower than the former value but bore no distinct relation to the latter. In the opinion of these authors the wilting coefficient "practically marks the cessation of growth," and after this point has been reached the soils continue to lose water through the tissues of the plants, even after they are dead, the final moisture content of the soil being as low as though the soil and air had been in direct contact. However, pot experiments of any kind, and especially those employing shallow vessels, appear ill adapted to answer the question as to how dry a particular soil may become under field conditions. Accordingly the data obtained in the field at such times as when the weather conditions have been favorable to an extreme reduction of the subsoil moisture should prove of especial interest, provided they are accompanied by determinations of the hygroscopic coefficient or wilting coefficient of the soils.

In regions of winter rains and summer droughts, such as California, one may safely count upon the continuance of hot rainless weather with clear skies for many weeks after the dry season has once set in, but in those with summer rains one never knows when to make preparations for studies that are dependent upon extreme brought conditions, and it may happen that, after all arrangements have been completed, several years may pass before weather conditions favoradle for the work occur. For this reason data on the soil moisture content during unusual droughts in humid regions are most apt to be secured in the course of some less specialized investigation.

Location of prairies sampled

The fields from which we secured the following data form two groups, one in the southwestern corner of Nebraska adjacent to the towns of McCook, Wauneta, Imperial, and Madrid; and the other close to the Nebraska Experiment Station at Lincoln. As all the former were at a distance of 200 miles or more from the experiment station, the sampling of them was feasible only at long intervals, and many of the data from these were secured incidental to the collection of samples for chemical studies. The western group of fields is beyond question well within the semi-arid region, while those at Lincoln lie almost as far to the west as the strictly humid climate extends on the American prairies. Some may consider that even Lincoln falls within the eastern limit of the great semi-arid region, but the composition of the soil (4, p. 414), the growth of vegetation and its agricultural history, as well as the moisture conditions of the subsoil distinguish it from the drier country west of Holdrege. All the factors which determine the difference in climate alter so gradually from east to west that it is impossible to place any definite line of demarcation between the humid and the semi-arid regions, the most that we are justified in assuming being that for every advance of a few miles to the westward of Hastings there is a nearer approach to strictly semi-arid conditions. At Hastings we appear to be still within the humid region, while at Holdrege, 50 miles farther west, most of the characteristics of semi-arid regions are discernible. Also the distribution of carbonates in the subsoil indicates that the district between Hastings and Holdrege is the region of most rapid transition (4, p. 414).

Favorable weather conditions

The weather of the period covering our work proved extremely favorable for the development of dry subsoils in both localities. At Lincoln it included the driest two-year period (1911–1912) of the past 20 years, 1897 to 1916, although in two years, 1895 and 1901, there had been a lower annual precipitation than in either of these (table I). Accordingly the soil moisture conditions we found there may be considered to include those representing the effects of extreme drought.

In southwestern Nebraska our work was begun in seasons, 1907 and 1908, forming the conclusion of a series of wet years. This was followed by a prolonged dry period, reaching its climax in

TABLE I

RELATION OF ANNUAL PRECIPITATION AT LINCOLN, YEAR BY YEAR, TO NORMAL (=100), 27.51 INCHES, SHOWING RELATIVE DRYNESS OF PERIOD OF OBSERVATION (1906 TO 1912).

Year	Percentage	Year	Percentage	Year	Percentage	Year	Percentage
1895....	60	1901....	80	1907....	99	1913....	95
1896....	138	1902....	150	1908....	130	1914....	145
1897....	93	1903....	126	1909....	126	1915....	128
1898....	102	1904....	101	1910....	114	1916....	80
1899....	82	1905....	129	1911....	89	.....	.....
1900....	123	1906....	124	1912....	81	.....	.....

1910–1911, the precipitation in 1910 being the lowest recorded since observations were begun at North Platte 42 years ago (table II). By 1911 the subsoil moisture had probably been reduced to as

TABLE II

ANNUAL PRECIPITATION IN INCHES AT STATIONS IN SOUTHWESTERN NEBRASKA

Length of record in years*	McCook 16	Wauneta 27	Imperial 26	H. O. Ranch 11	North Platte 42
Normal	19.71	18.70	20.79	17.80	18.88
1905	33.97	32.24	33.05	.....	26.81
1906	20.59	22.82	26.23	20.14	27.99
1907	19.32	20.18	16.76	12.02	19.61
1908	18.08	24.77	26.27	21.01	19.96
1909	22.54	18.46	26.03	16.89	22.41
1910	9.34	13.82	11.77	7.62	10.70
1911	12.15	18.82	17.37	12.76	17.43
1912	14.69	20.00	24.58	20.74	18.69
1913	18.26	16.05	16.60	14.99	19.10
1914	18.24	17.26	16.94	19.42	15.79
1915	30.95	27.04	37.14	35.84	32.70
1916	15.35	14.95	19.33	14.60	12.96
Maximum	33.97	32.24	37.14	35.84	32.70
Minimum	9.34	13.82	11.77	7.62	10.70

* To end of 1916.

low a point as is ever experienced in southwestern Nebraska. The climate of the Nebraska portion of the Transition Region, including both groups of fields, has been discussed in some detail in a previous paper dealing with the composition of its loess soils (2).

Experimental methods

In taking the samples we used augers provided with extensions, commonly employing two sizes, one 1.5 inches in diameter with which to take the sample, and another 2.0 inches in diameter to enlarge and clean out the hole preparatory to sampling the next lower section. In many of the borings in western Nebraska the subsoil in part or in all the levels sampled was too dry to be removable by the ordinary auger, sliding off the bit as this was being withdrawn. In such cases we employed a Tinsley "auger with casing" (11), the sleeve on this retaining the soil loosened by the bit. Except where otherwise indicated, the samples were composites from 3 borings 10–20 yards apart. Composites were made from the first 3 borings only where it could be seen from the behavior of the soil toward the auger that the general moisture conditions in all 3 were similar, but not necessarily identical.

Extremes under semi-arid conditions

AFTER A PROLONGED DROUGHT.—As already stated, 1910 proved the driest year in southwestern Nebraska since observations were begun, the precipitation amounting to scarcely half the normal (table III). The autumn of this year and the following winter and spring were practically without snow or rain until April, the total precipitation at McCook from the end of August 1910 to the first of the following April amounting to only 1.60 inches (table IV), and this fell in such small amounts as to influence the soil moisture content through only a negligible distance. At Imperial and Wauneta the weather was not quite so dry, but the difference was not sufficient to cause an appreciable difference in the moisture content of the subsoil.

The samplings made in fields near McCook and Wauneta near the end of October 1910 showed such low ratios of moisture content to hygroscopic coefficient (table V) that some undiscovered source of error was suspected, and for this reason 6 weeks later we resampled two of them, A and B at McCook, and took sets from two additional fields. These confirmed the correctness of the extremely low ratios. The concordance of the moisture content with the hygroscopic coefficient was very striking, as though the

plant roots, while not recognizing the wilting coefficient, practically ceased to withdraw water as soon as the hygroscopic coefficient had been reached. There was little difference in moistness between

TABLE III

MONTHLY PRECIPITATION IN INCHES AT MCCOOK, WAUNETA, IMPERIAL, AND THE H. O. RANCH, SHOWING DRYNESS OF SEASONS

MONTH	NORMAL			1910			
	McCook	Wauneta	Imperial	McCook	Wauneta	Imperial	H. O. Ranch
January	0.21	0.26	0.44	0.0	0.0	0.40	0.35
February	0.62	0.69	0.69	0.0	0.0	0.10	0.06
March	0.73	1.03	1.33	0.0	0.0	0.38	0.36
April	1.89	2.04	2.27	0.76	0.82	0.71	0.60
May	2.82	2.54	2.82	2.77	2.00	1.98	2.25
June	3.29	3.34	3.34	1.12	3.44	2.51	1.24
July	3.09	2.47	2.91	0.70	0.77	0.72	0.34
August	2.55	2.74	2.73	2.93	2.64	2.82	0.97
September	1.72	1.35	1.34	0.72	3.20	1.58	1.28
October	1.03	1.13	1.10	0.17	0.0	T	0.0
November	0.56	0.39	0.50	0.0	0.10	T	0.03
December	0.57	0.57	0.72	0.17	0.85	0.57	0.14
Annual	19.08	18.55	20.19	9.34	13.82	11.77	7.62

MONTH	1911				1912			
	McCook	Wauneta	Imperial	H. O. Ranch	McCook	Wauneta	Imperial	H. O. Ranch
January	0.05	0.10	0.42	0.15	0.0	0.20	0.52	0.15
February	0.47	0.70	0.37	0.31	0.24	1.51	1.08	1.00
March	0.12	0.50	0.22	0.03	1.50	2.35	3.61	2.70
April	1.72	3.45	2.55	1.94	2.01	2.82	2.85	1.74
May	1.25	1.75	2.19	1.29	0.0	0.95	1.41	1.53
June	0.66	1.35	1.29	0.92	2.77	1.89	1.82	1.80
July	0.84	1.30	1.10	0.84	2.29	3.26	5.09	5.16
August	4.34	3.07	3.45	1.97	2.11	2.78	4.28	2.49
September	0.59	1.80	1.44	0.86	2.13	2.61	2.01	2.41
October	0.96	3.30	2.92	2.85	1.09	1.43	1.55	1.45
November	0.05	0.0	0.10	0.05	0.50	0.20	0.15	0.0
December	1.10	1.50	1.32	1.55	T	0.0	0.21	0.05
Annual	12.15	18.82	17.37	12.76	14.69	20.00	24.58	20.44

the surface foot and the succeeding 2 or 3 ft., and even the deeper subsoil was but little if at all moister. At no level and in none of the fields was there any growth water, the moisture content being below the computed wilting coefficient, which corresponds to a ratio of 1.47, or approximately 1.5 (6).

TABLE IV

DAILY PRECIPITATION AT McCOOK FROM SEPTEMBER 1, 1910, TO JUNE 30, 1912

	1910				1911											1912					
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
1	.....	.....	.....	.....	0.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T	.....	.....	.....
2	.....	0.17	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.57	.....	.....	.....	.....	.....	.....	0.80	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	0.89	.....	0.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	0.07	0.57	0.12	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	0.15	.....	.....	0.10	.....	.....	.....	.....	.....	.....	0.07	0.47	.....	.....	T	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.22	.....	0.06	.....	.....	.....	.....	.....	.....	.....	0.15
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.05
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T	.....	.....	.....	0.95
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.33
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	T	.....	.....	.....	.....	.....	.....	0.47
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.77	.....	.....	.....	.....	.....	0.08	0.60	.....	.....	0.10
13	.....	.....	.....	0.07	.....	.....	.....	.....	.....	.....	0.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.41	.....	.....	.....	.....	.....	.....	.....	.....
16	.....	.....	.....	.....	.....	0.25	.....	.....	.....	0.18	.....	.....	.....	0.49	0.05	.....	.....	.....	.....	.....	.....	0.38
17	.....	.....	.....	.....	.....	0.08	.....	0.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.43	.....	.....	.....	T	.....	.....	.....	.....	.....	0.07
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.73	0.19	.....	.....	0.95	.....	.....	.....	0.55	.....	.....
21	0.23	.....	.....	.....	.....	.....	.....	.....	1.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.10	.....	.....	.....
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	0.34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....	.....	.....	.....	.....	0.15	.....	0.11	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	.....	0.12	.....	.....	.....	.....	0.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	.....	.....	.....	.....	.....	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.05	.....	1.38	.....	.....
29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.28	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	.....	.....	.....	.....	.....	.....	.....	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total.	0.72	0.17	0.0	0.17	0.05	0.47	0.12	1.72	1.25	0.66	0.84	4.34	0.59	0.96	0.05	1.10	0.0	0.24	1.50	2.01	0.0	2.77

TABLE V

MOISTURE CONDITIONS AT McCOOK AND WAUNETA, AUTUMN 1910

A: McCOOK

DEPTH	OCTOBER 24		OCT. 26	OCT. 27	DECEMBER 9		DECEMBER 10	
Foot	Field A	Field B	Field C	Field D	Field A	Field B	Field D	Field E
	HYGROSCOPIC COEFFICIENTS							
1	9.2	9.5	10.2	8.8	9.1	10.0	9.3	10.6
2	10.7	11.4	11.3	10.9	10.4	10.1	10.9	9.9
3	10.4	9.1	10.2	10.7	10.2	9.1	10.7	8.2
4	10.1	8.6	8.4	10.8	9.3	7.8	9.6	8.1
5	9.4	8.5	8.6	.....	8.7	8.2	9.7	7.9
6	8.7	8.4	9.0	8.5	8.2	8.2	11.7	7.5
Average	9.8	9.1	9.6	9.6	9.3	8.9	10.3	8.7
	RATIOS							
1	0.8	0.8	0.8	0.8	1.1	0.9	0.9	0.9
2	0.9	0.8	0.9	0.8	1.0	0.8	0.8	0.9
3	0.9	0.8	0.8	0.8	1.0	0.9	0.8	0.9
4	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0
5	0.9	1.1	1.0	.....	1.1	1.0	1.0	1.0
6	1.2	1.1	0.9	1.0	1.1	1.1	0.9	1.1
Average	0.9	0.9	0.8	0.9	1.0	0.9	0.9	1.0

B: Wauneta

DEPTH	OCTOBER 31	NOVEMBER 1		NOVEMBER 2	NOVEMBER 3
Foot	Field A	Field B	Field C	Field D	Field E
	HYGROSCOPIC COEFFICIENTS				
1	8.8	9.9	9.5	8.5	8.1
2	9.5	10.1	9.4	9.3	9.5
3	8.7	10.6	7.7	9.7	9.7
4	8.9	10.7	8.6	9.5	8.7
5	10.0	9.8	7.6	8.7	7.3
6	10.3	8.7	7.6	8.0	6.4
Average	9.4	10.0	8.4	8.9	8.3
	RATIOS				
1	0.9	0.8	0.9	1.0	0.9
2	0.8	1.0	0.9	0.8	1.0
3	0.9	0.9	1.0	0.8	0.9
4	1.0	1.0	0.9	0.8	1.0
5	1.0	0.9	1.0	0.9	1.1
6	1.1	1.2	1.1	1.1	1.3
Average	0.9	1.0	1.0	0.9	1.0

Some 4 months later 3 of the fields at McCook and Wauneta were sampled again and one added at the latter place. The

TABLE VI

MOISTURE CONDITIONS IN WESTERN NEBRASKA IN LATE SPRING OF 1911, FOLLOWING VERY DRY AUTUMN, WINTER, AND EARLY SPRING

DEPTH	McCOOK		WAUNETA		IMPERIAL				
	Mar. 24	Mar. 25	April 4		April 1	April 3	April 12	April 12	April 14
Foot	Field B	Field E	Field E	Field F	Field A	Field B	Field C	Field D	Field E
	HYGROSCOPIC COEFFCIENTS								
1	9.6	8.7	8.7	9.0	6.4	8.3	3.0	2.0	3.6
2	10.5	10.1	9.2	9.6	7.9	10.7	2.6	2.2	4.6
3	9.1	9.6	9.1	10.9	8.1	9.0	2.4	2.0	5.9
4	8.3	9.0	9.2	10.0	6.8	7.8	4.1	2.0	4.8
5	8.1	8.6	9.6	8.8	4.2	6.8	4.5	2.1	4.4
6	8.1	9.0	8.3	7.7	3.9	6.8	4.5	2.0	3.6
7	8.1	7.9	6.6	6.7	4.0	.....	5.1	1.9	4.2
8	8.3	8.6	5.7	7.3	5.3	.....	4.3	2.5	8.4
9	8.1	8.4	4.9	7.0	6.0	.....	3.5	2.0	5.4
10	8.1	8.4	4.4	7.0	.....	.....	.....	.....	.....
11	8.1	8.6	4.0	7.9	.....	.....	.....	.....	.....
12	8.1	8.6	3.7	7.4	.....	.....	.....	.....	.....
13	.....	.....	4.3	6.6	.....	.....	.....	.....	.....
14	.....	.....	4.2	6.5	.....	.....	.....	.....	.....
15	.....	.....	5.1	6.4	.....	.....	.....	.....	.....
Average	8.9	9.2	9.0	9.3	6.2	8.2	3.5	2.1	4.5
	RATIOS								
1	0.8	0.8	1.0	1.0	0.8	0.9	1.2	1.1	0.7
2	0.8	0.9	0.8	0.9	0.9	0.9	1.5	1.1	0.9
3	0.9	0.9	0.9	0.8	0.9	0.8	1.2	1.1	0.9
4	0.9	0.9	1.1	0.8	0.9	0.8	1.1	1.2	0.9
5	1.0	1.0	1.3	0.9	1.0	1.0	1.2	1.0	0.9
6	1.1	0.9	1.2	1.0	1.0	1.0	1.0	1.1	1.0
7	1.1	1.1	1.5	1.1	1.1	.....	1.1	1.4	1.4
8	1.1	1.1	1.5	1.0	1.2	.....	1.2	1.2	1.2
9	1.1	1.1	1.5	1.1	1.3	.....	1.2	1.4	1.3
10	1.2	1.1	1.5	1.1	.....	.....	.....	.....	.....
11	1.2	1.0	1.6	1.0	.....	.....	.....	.....	.....
12	1.2	1.1	1.8	1.1	.....	.....	.....	.....	.....
13	.....	.....	1.6	1.2	.....	.....	.....	.....	.....
14	.....	.....	1.7	1.1	.....	.....	.....	.....	.....
15	.....	.....	1.7	1.2	.....	.....	.....	.....	.....
Average 1–6	0.9	0.9	1.0	0.9	0.9	0.9	1.2	1.1	0.9

sampling was carried down to the twelfth or fifteenth foot on this occasion (table VI). The subsoil was not found appreciably drier than when first sampled. As 4 or 5 months of rainless weather had

intervened, it would appear that the loss of moisture by transpiration during the winter must have been very slight.

It is of interest that in the spring of 1911 the subsoil at depths of 7–15 ft. in field E at Wauneta was found quite moist, showing an average ratio of 1.6. The explanation of this will be discussed in a later paragraph.

On the last occasion samples were taken from near Imperial also. While the soil and subsoil in all of the fields at McCook as deep as sampled, and in all those at Wauneta except in the lower levels of E and F, were derived from the loess, and showed hygroscopic coefficients between 7.5 and 11.0, all the soils and subsoils at Imperial were residual in origin with hygroscopic coefficients varying all the way from 2.0 to 10.7. At Imperial, in contrast to McCook and Wauneta, we sampled some fine sandy loams as well as the more numerous fine textured soils, none of the latter, however, being of loessial origin. Comparing the ratios it will be seen that the prairies with the finer soil, A, B, and E, were as dry in the first 6 ft. as those at Wauneta and McCook, and that the one of the two with sandy soil and subsoil, C and D, was but slightly more moist. Below the sixth foot they were distinctly moister, but in none of them was the ratio much above 1.0. The reduction of the moisture content to the hygroscopic coefficient was general and was independent of the relative hygroscopicity.

AFTER A WET WINTER FOLLOWING A PROLONGED DROUGHT.—Until the spring of 1912 no more sampling was done at McCook, Wauneta, or Imperial. The weather of the intervening months had been unfavorable for any marked increase in the moisture content of the deeper subsoil, although very favorable for moistening the surface foot. April and May of 1911 had a rainfall somewhat below normal, June and July were very dry, while during August and the first few days of September considerably more rain than usual fell. The rest of September was dry, but the precipitation of October was 3 times the normal and of such a character that there was little chance for run-off; as vegetation had become dormant the loss by transpiration must have been slight. November was very dry, but the precipitation of December was twice the normal, a heavy rain on December 20 further moistening the

surface soil. January and February together had a precipitation somewhat below normal at McCook, but above at both Wauneta and Imperial, while March at all 3 places had a precipitation 2 or 3 times the normal. April was rainless until the 20th, between which date and the 28th from 2 to 3 inches of rain fell.

Sampling was carried out at McCook on May 7 and 8, no rain having fallen since April 28; at Imperial on May 11, 13, and 14, 0.45 inch having fallen there in 4 light showers; and at Wauneta on May 16 and 17. At the last place the only rain since April 28 had been one of 0.10 inch on May 10. Thus conditions had been ideal for the downward movement of the water into the subsoil, while at each place an interval of 8–19 days had elapsed between the last good rain and the date of sampling.

The generally favorable weather of autumn, winter, and spring was evidenced by the circumstance that in the early spring the outlook appeared unusually promising for the farmers. Wheat had come through the winter in fine condition and preparations were being made for seeding a large acreage to spring grains, the prospects being considered so favorable that local merchants were willing to furnish seed grain in return for a reasonable share of the crop. Conditions appeared ideal for a study of the degree to which the ratio in the surface soil had to be raised before water could pass downward into the deeper portions of the subsoil, where during the previous year the moisture had been reduced to the hygroscopic coefficient or even slightly below.

In the fields with heavier soil we found that the moisture content had been distinctly affected at McCook (table VII) to only 2 ft., at Wauneta in the one field to 3 ft., in the other to 4 ft. or more, and in the only one sampled at Imperial to 5 ft.

IN NORMAL SEASONS.—That the low ratios prevailing throughout the subsoil of the prairies after severe droughts, as illustrated in the preceding tables, are not entirely absent even in favorable seasons, may be seen from table VIII reporting conditions at the H. O. Ranch. There, as at McCook, Wauneta, and Imperial, after periods of drought the ratio was found not far from 1.0 at all depths, while under more favorable conditions, as in July 1908, the low ratio was still to be found at some level within the first 6 ft.

While after protracted droughts and probably also after extremely wet periods the moisture conditions in the subsoil are quite uniform, they vary much from place to place under more normal weather conditions, as illustrated by table IX.

TABLE VII

MOISTURE CONDITIONS IN WESTERN NEBRASKA IN MAY 1912, AFTER WET WINTER AND SPRING

DEPTH	McCOOK			WAUNETA		IMPERIAL					
Foot	May 7	May 7	May 8	May 16	May 17	May 11			May 13		May 14
	Field A	Field B	Field E	Field B	Field C	Field E	Field G	Field H	Field I	Field J	Field K
	HYGROSCOPIC COEFFICIENTS										
1	8.4	9.6	10.1	9.2	7.5	8.2	1.6	2.6	7.1	5.8	3.2
2	9.6	10.3	10.1	10.4	9.1	10.2	2.6	3.7	7.5	6.3	3.2
3	8.1	8.3	.....	10.0	9.0	8.9	1.9	3.5	9.7	7.1	5.4
4	8.7	7.5	.....	9.6	9.5	5.3	1.5	3.5	9.0	5.1	3.7
5	8.4	7.8	7.3	8.4	8.4	4.7	1.3	1.6	.....	.....	3.4
6	7.2	7.6	.....	7.6	6.8	4.9	1.3	1.3	.....	.....	3.0
Average	8.4	8.5	.....	9.2	8.4	7.0	1.7	2.7	.....	.....	3.7
	RATIOS										
1	2.6	2.1	2.1	2.0	2.3	2.0	2.5	2.9	2.4	2.1	2.4
2	1.4	1.4	1.3	1.9	2.2	1.7	2.1	2.8	2.4	2.3	3.5
3	1.1	1.1	.....	1.4	1.6	1.3	4.2	2.7	1.5	1.3	2.0
4	1.0	1.1	.....	1.0	1.3	1.2	4.6	2.3	1.1	1.2	1.1
5	1.1	1.0	1.0	1.1	1.2	1.2	4.5	3.1	.....	.....	1.1
6	1.3	1.1	.....	1.2	1.3	1.0	4.7	3.4	.....	.....	1.2
Average	1.4	1.3	.....	1.4	1.6	1.4	3.8	2.9	.....	.....	1.9

Computations from data of Shantz and of Burr

The only data reported by other investigators that may be used for comparison with our own appear to be those secured by SHANTZ at Akron, Colorado, in 1909, and by BURR at North Platte, Nebraska, in 1912. While neither of these authors reports the hygroscopic coefficients of the soils, each gives the wilting coefficients for a representative set of samples, these having been computed from the determined moisture equivalents. From these data we have computed the hygroscopic coefficients by means of the Briggs-Shantz formula (**6**, p. 65): hyg. coef. = wilt. coef. $\times 0.68$.

For the period June 7–September 27, 1909, SHANTZ determined the moisture content twice a day in a grama-buffalo grass association, recording it in 6-inch sections to a depth of 3 ft. and in foot sections through the succeeding 3 ft. From his data we find that on August 7–8 and 10–11 the ratio of the moisture content to the

TABLE VIII

DATA FROM H. O. RANCH IN DIFFERENT YEARS, INCLUDING THE FAVORABLE SEASONS OF 1907 AND 1908

DEPTH	1907	1908		1910		1911	1913
Foot	Nov. 22	April 30	July 29	March 24	Sept. 21	April 21	July 13
	HYGROSCOPIC COEFFICIENTS						
1	7.7	8.5	8.0	8.7	8.8	8.9	8.4
2	10.3	9.8	9.7	9.7	11.5	11.1	
3	10.1	9.8	11.3	10.4	9.2	10.5	
4	7.7	8.3	7.7	8.7	7.9	8.6	8.6
5	7.1	6.9	6.4	7.9	7.5	8.5	
6	7.2	7.4	6.3	7.5	6.5	7.5	
7	6.4	.....	5.9	6.8	.....	7.2	
8	.....	.....	5.1	6.1	.....	6.8	6.4
9	8.3	.....	5.9	6.0	.....	7.7	
Average 1–6	8.3	8.4	8.2	8.8	8.6	9.2	7.6
	RATIOS						
1	1.9	1.2	2.1	2.1	1.2	0.7	0.9
2	1.1	1.1	2.0	1.2	0.8	0.8	
3	1.1	0.9	1.1	1.0	0.8	0.8	
4	1.3	1.0	1.4	1.0	0.9	0.9	0.9
5	1.5	1.1	1.6	1.0	0.9	1.0	
6	1.8	1.1	1.8	1.1	1.1	1.1	
7	1.8	.....	1.5	1.1	.....	1.1	
8	.....	.....	1.6	1.1	.....	1.2	1.2
9	.....	.....	1.3	1.1	.....	.....	
Average 1–6	1.5	1.1	1.7	1.2	0.9	1.0	1.0

hygroscopic coefficient in the 7–12 and 13–18 inch levels fell to approximately 1.0 (**10**, p. 35); while from July 22 to September 9 the ratio at the latter depth was almost continuously much below 1.5. From August 7 to 13 the sixth foot, and to a less extent the fifth, showed ratios close to 1.0. In each of the 4 months included in the study the rainfall was much above the normal for Akron, the excess varying from 25 to more than 100 per cent (**8**), and

averaging at least 50 per cent above the normal. There was no actual drought at any time during the season, but there were two rather dry periods, June 14–July 6 and July 11–25, in which light rains gave totals of 0.20 and 0.09 inch respectively.

When the subsoil at Akron, even in that unusually wet summer, had its moisture content reduced to such a low point, it is probable

TABLE IX

DATA FROM 6 INDIVIDUAL BORINGS ON THE H. O. RANCH, NOVEMBER 22, 1907, ILLUSTRATING VARIATIONS FROM BORING TO BORING

DEPTH	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	Average	Maximum	Minimum
Foot	HYGROSCOPIC COEFFICIENTS								
1	6.9	7.4	7.8	7.6	7.2	6.1	7.1	7.8	6.1
2	8.4	8.6	10.4	10.2	8.3	6.7	8.8	10.4	6.7
3	7.3	6.7	10.2	10.0	8.1	7.5	8.4	10.2	6.7
4	8.5	5.1	7.0	8.4	9.9	7.7	7.9	9.9	5.1
5	7.3	4.2	7.0	7.1	11.8	6.7	7.3	11.8	4.2
6	7.2	5.3	7.8	6.5	9.9	5.4	7.0	9.9	5.3
7	7.9	6.7	6.9	6.0	9.2	5.2	7.3	9.2	5.2
Average 1–7	7.6	6.5	8.1	8.0	9.2	6.5	7.6	9.2	6.3
	RATIOS								
1	1.6	1.7	1.8	1.9	1.7	2.0	1.8	2.0	1.6
2	1.3	1.1	1.2	1.1	1.2	1.5	1.2	1.5	1.1
3	1.3	1.1	1.1	1.1	1.2	1.1	1.2	1.3	1.1
4	1.2	1.1	1.5	1.1	1.1	1.2	1.2	1.5	1.1
5	1.2	1.3	1.7	1.3	1.4	1.2	1.3	1.7	1.2
6	1.3	1.4	1.7	2.0	1.4	1.3	1.4	2.0	1.3
7	1.3	1.7	1.9	1.8	1.2	1.4	1.5	1.9	1.2
Average 1–7	1.3	1.3	1.6	1.5	1.3	1.4	1.4	1.6	1.3

that in a really dry season the ratios would be found as low as those we encountered in southwestern Nebraska.

The root systems of the native plants were studied by SHANTZ, but the penetration of the grama and buffalo grasses he indicates (10) would not account for the removal of available moisture from below the first foot or two.

BURR (7) reports data from a prairie sampled in the spring, summer, and early autumn of 1912 (table X). In the spring high ratios were shown in the first 2–3 ft., but by the end of June the

ratios at all levels sampled had fallen to practically 1.0 and so remained through the remainder of the season, there being no evidence of further drying of the subsoil.

Thus the data of both SHANTZ and BURR confirm our findings regarding the stage of dryness to which the subsoil may be reduced in a dry season by the short grass vegetation, while those of the latter author agree also with our view that after the subsoil moisture content has been reduced to approximately the hygroscopic coefficient it suffers but little, if any, further lowering through a continuation of the drought conditions, and not with that of BRIGGS and SHANTZ that the subsoil continues to lose water through the plant tissues until it approaches an air-dry condition (**6,** p. 8).

TABLE X

RATIO OF MOISTURE CONTENT TO HYGROSCOPIC COEFFICIENT IN A PRAIRIE FIELD AT NORTH PLATTE IN 1912, COMPUTED FROM DATA OF BURR

Depth foot	Hygroscopic coefficient*	April			May		June		July		Aug.	Sept.
		18	22	29	11	25	10	29	25	26	22	12
1.....	6.8	2.5	3.3	3.3	3.1	2.0	1.4	0.8	1.0	1.8	0.8	1.5
2.....	6.8	1.9	2.2	3.2	2.6	2.2	1.3	0.8	0.9	0.9	0.8	0.9
3.....	6.8	1.2	1.2	1.7	2.3	2.0	1.6	0.9	0.9	0.9	0.8	0.9
4.....	6.8	1.1	1.2	1.2	1.4	1.5	1.4	0.9	1.0	1.1	0.9	0.9
5.....	7.5	1.1	1.1	1.2	1.2	1.2	1.3	0.8	1.0	1.1	0.8	0.8
6.....	7.5	1.1	1.2	1.2	1.0	1.1	1.2	0.7	0.9	1.1	0.8	0.9

* Computed from wilting coefficients of a representative set of samples (7).

Extremes in eastern Nebraska

The periods of extreme drought at Lincoln were not numerous, and usually when these came an examination with the soil auger showed that the moisture content of even the surface foot or two was well above the hygroscopic coefficient, and as it was only the minimum moisture content that we were seeking in these prairie fields we report data from only a few sets of samples. On only 3 occasions in the 6-year period (1906–1912) did we find in the surface 2–3 ft. the dry condition which indicates the approaching exhaustion of available moisture (table XI).

The first sampling, on August 23, 1909, had been preceded by a comparatively dry period of 42 days, during which only 1.57 inches of rain had fallen; none had fallen in the last 20 days, while the

weather had been unusually hot and windy. The time of the season was that at which the draft upon the subsoil moisture might be expected to show the most marked effect. In the soil of the first foot we found a ratio of 1.0 and in that of the next 3 ft., an average ratio of 1.4; but the sixth foot, with a ratio of 1.9, appeared to have lost but little of the moisture which it could retain against downward movement.

TABLE XI

MOISTURE CONDITIONS IN PRAIRIE FIELDS NEAR LINCOLN AFTER UNUSUALLY DRY PERIODS

AUGUST 23, 1909			AUGUST 3, 1911			JUNE 7, 1912		
Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio
1.....	10.9	1.0	1.....	10.5	1.4	1.....	13.4	1.5
2.....	10.8	1.3	2–5...	13.1	1.3	2.....	15.2	1.3
3.....	11.5	1.5	6–8...	12.3	2.0	3.....	14.1	1.2
4.....	14.0	1.5	9.....	12.8	2.1	4.....	13.9	1.2
5.....	12.5	1.6	.....	.....	.....	5.....	12.5	1.5
6.....	11.8	1.9	.....	.....	.....	6.....	12.2	1.9

On the second occasion, August 3, 1911, a dry period of 65 days had just been ended by a rain of 0.84 inch. Compared with a normal precipitation of 9.0 inches for this period, only 2.68 inches of rain had fallen, and this in light showers, while both the mean temperature and the wind velocity had been somewhat above the normal. As the subsoil of the second to the fifth foot appeared uniformly dry it was combined into a single sample, the ratio proving to be 1.3, but in the sixth to ninth foot it was 2.0 to 2.1. The moister condition in the surface foot indicated in the table was due to a shower of the day before having moistened the immediate surface layers.

From the time of the preceding to the next and last sampling, June 7, 1912, the weather on the whole was very unfavorable to the accumulation of any moisture in the subsoil, and the spring of 1912 was exceptionally favorable to the exhaustion of whatever available water was within reach of the plant roots. The moisture conditions found were quite similar to those on the preceding occasion.

Thus the samplings, taken at times of drought when one might have expected almost the lowest moisture content in the subsoil

ever to be found in prairie fields at Lincoln, showed dry subsoil only within the first 5 ft., below this depth the ratios lying between extremes of 1.9 and 2.7, or in general between 2.0 and 2.4, the moisture retaining capacity of the subsoil. On only one occasion, and then only in the first foot, was the moisture content found reduced as low as the hygroscopic coefficient, and there it is to be attributed to the surface few inches of the foot section having been dried by evaporation to a point much below this value, with the result that the average for the whole foot section shows a low ratio.

In this connection it is of interest to know the ratios which normally prevail in the deeper subsoil of the eastern prairies. In April 1911, a field situated on a gentle slope and 50 ft. or more above ground water was sampled to a depth of 18 ft. (table XII). Below the fifth foot ratios ranging only between 2.1 to 2.4 were found.

TABLE XII

MOISTURE CONDITIONS IN PRAIRIE NEAR LINCOLN, APRIL 13, 1911, SHOWING NORMAL CONDITION OF DEEPER SUBSOIL

Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio
1.....	11.8	2.5	7....	13.0	2.2	13....	12.3	2.2
2.....	15.3	2.0	8....	12.8	2.2	14....	12.0	2.4
3.....	14.3	1.8	9....	13.6	2.1	15....	12.3	2.3
4.....	14.2	1.8	10....	12.1	2.4	16....	10.3	2.3
5.....	13.6	1.9	11....	13.4	2.1	17....	9.8	2.3
6.....	13.1	2.1	12....	13.0	2.2	18....	10.9	2.2

Thus as near the surface as the sixth foot, when conditions were such as to develop the driest subsoil, the ratio was not much below that found in the deep subsoil under normal conditions. This failure of the natural vegetation of the prairies of eastern Nebraska to exhaust the free water of the deeper subsoil is in sharp contrast with the conditions found on the short-grass prairies of the southwestern part of the state, as previously described. That this moist condition is due to a difference in the conduct of the native plants and not to any peculiar properties of the humid subsoil is evident from the fact that in the alfalfa fields adjacent to the prairies kept under observation the ratios were quite commonly found reduced as low as 1.2 to 1.4 to a depth of 15 or 20 ft.,

or even more (table XIII). In an oak grove planted on the prairie some 30 years before and sampled on practically the same dates

TABLE XIII

MOISTURE CONDITIONS IN EASTERN NEBRASKA ALFALFA FIELD, ADJACENT TO PRAIRIE REPORTED IN TABLE XII, SHOWING FAILURE OF PRAIRIE VEGETATION TO REDUCE MOISTURE CONTENT OF DEEPER SUBSOIL NOT DUE TO ANY PECULIARITY OF SUBSOIL

APRIL 13, 1911			SEPTEMBER 12, 1912			
			Boring 1		Boring 2	
Depth foot	Hygroscopic coefficient	Ratio	Hygroscopic coefficient	Ratio	Hygroscopic coefficient	Ratio
1.....	11.6	2.4	13.2	1.4	12.9	1.3
2–6.....	13.4	1.7	13.7	1.1	13.5	1.1
7–12.....	11.0	1.5	12.4	1.1	12.1	1.1
13–18.....	8.5	1.5	10.5	1.1	10.8	1.1
19–21.....	11.5	1.4	11.8	1.2	12.1	1.1

as the prairie fields, the subsoil moisture was found to be affected to a greater depth than in the latter, the drying effect extending apparently to at least 15 ft. (table XIV).

TABLE XIV

MOISTURE CONDITIONS IN AN OAK GROVE NEAR LINCOLN

AUGUST 23, 1909			AUGUST 2, 1911			JULY 5, 1912		
Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio	Depth foot	Hygroscopic coefficient	Ratio
1.....	10.1	1.1	1.....	9.1	1.8	1....	10.0	0.7
2.....	11.7	1.3	2–9...	12.4	1.3	2....	11.8	1.7
3.....	14.2	1.3	10–14.	11.9	1.6	3....	14.2	1.4
4.....	14.1	1.2	15....	12.0	1.6	4....	14.1	1.2
5.....	13.9	1.2	.....	.....	.....	5....	14.0	1.2
6.....	13.4	1.2	.....	.....	.....	6....	13.5	1.2

Discussion

The moisture conditions in the deeper subsoil of the prairies are very dissimilar according to whether we deal with humid or with semi-arid fields. In the former at depths below 6 ft. the subsoil appears always moist, even after the severest drought, while in the latter the extreme dryness indicated by ratios of 1.0–1.2 is in general persistent in the deeper subsoil, extending to a depth of

12 ft. or more after prolonged droughts, and even in wetter seasons is commonly found in one or more foot levels within the first 6 ft. That the lack of dryness in the deeper subsoil of the humid prairies is not due to any peculiarity of the subsoil is evident from the observation that a fair stand of alfalfa may in the course of a few years reduce the moisture content almost to the hygroscopic coefficient to a depth of 20 ft. or more.

In our deep cylinder experiments (1) the exhaustion of free water was observed only within the zone of root development, and in our recently reported study of the movement of water in the absence of plants (3) we found no appreciable transfer of water from a moister to a drier portion of a soil when the ratio in the former was as low as 1.5 and that in the latter between 1.5 and 1.0.

If we assume that movement of water through a soil ceases when the ratio in the moistest portion has fallen as low as 1.5; that the deeper subsoil loses water through upward movement only when it is penetrated by plant roots; and, lastly, that plants are able to develop roots into a soil layer only when this has a moisture content above the computed wilting coefficient (5), the ratio 1.5, we must conclude that the roots responsible for the dry condition (indicated by ratios of 1.1–1.4) encountered in any subsoil level either will be found surviving or that they have died only since this level of the subsoil was last reduced to the dry condition.

In order to explain how the dry condition of the deeper subsoil is first established and how it is renewed after wet periods, it seems necessary to assume that among the shallow rooted grasses there are distributed a considerable number of very deep rooted perennials. After this dry condition of the deeper subsoil has once been established it may be maintained through a dry period of several successive years without the presence of any roots in it, the moisture from the rains and snow being held near the surface until it either evaporates or is transpired by the shallow rooted plants, while the upward movement of water from the moist zone beyond the extreme reach of plant roots is at least too slight to show a distinct effect. The absence of the dry condition in the deeper subsoil after prolonged droughts, such as illustrated by field E at Wauneta (table

VI), may be attributed to a temporary absence of the deep rooted perennials or to their fewness. The factors just mentioned are sufficient to account for the maintenance of a dry upper subsoil through which no roots could develop into the moist zone.

The question of whether the living roots are to be found in the deeper subsoil only during each successive wet period, they following the downward extension of the moist zone, continuing to withdraw water until the ratio approximates 1.0, and then dying off, or whether they continue alive but withdrawing practically no moisture throughout the dry periods of several years which intervene between the successive wet periods, is to be answered only by detailed field investigations, involving the use of pits or trenches 12–20 ft. deep.

The present moisture conditions of the deeper subsoil of the prairies, like their plant population, are to be regarded as the result of a slowly established equilibrium, and any alteration of the plant cover may greatly affect the subsoil moisture conditions. The complete suppression of plant life over an acre or more, a condition approached in young orchards and groves kept in clean cultivation, might during a series of wet years raise the moisture content of the deeper subsoil to its water-retaining capacity and maintain this with little change during the ensuing dry period. If such a field were neglected, however, it would soon be taken possession of by many species, most of them shallow rooted annuals, but some deeper rooting perennials, which, meeting little competition for moisture in the deeper subsoil, could develop an extensive root system there and gradually reduce the moisture to approximately the hygroscopic coefficient. Then, as on the prairie, this dry condition would be maintained except at such times as unusually wet seasons extended the moist zone far below its normal limits.

While it is evident from table VI that the lower limit of the dry zone in the deep loessial soils in the semi-arid region is more than 12–15 ft. below the surface we have no data showing its maximum depth. ROTMISTROV (9), from his studies near Odessa, concluded that there permanently moist subsoil in waste land occupied by weeds, etc., is first encountered at 14–30 ft. The depth to which the root systems of the deeper rooted prairie plants indicated by

SHANTZ (10) extend would not suffice to explain the dry condition of the deeper subsoil which we encountered.

The persistently moist condition of the deeper subsoil of the humid prairies is to be attributed to the fewness of the roots developed in them. When deep rooted perennial plants such as alfalfa or forest trees are introduced, their subsoil moisture is utilized to a much greater depth. It is evident that on these a forest once established should be able to maintain itself if protected from fires. The subsoil moisture conditions in general would indicate that the natural condition of grassland in eastern Nebraska is due to other causes than soil moisture conditions, while in western Nebraska it may be fully accounted for by those alone.

The distribution of carbonates in the first 6 ft. of soil in the prairies at McCook and Wauneta indicates that in prehistoric times the climate was similar to that now prevailing (4). Carbonates are found in the surface foot or two only in almost negligible quantities, while in the fourth, fifth, and sixth feet they constitute from 3 to 6 per cent of the weight of the soil.

Summary

1. During a 6-year period, in which the weather was exceptionally favorable for a study of the minimum moisture content of the subsoil, moisture studies were carried out on Nebraska prairies, both in the buffalo-grass formation in the southwestern part of that state, where the climate is typically semi-arid, and in the prairie-grass formation near Lincoln, which lies within the limits of the humid region. The fields were sampled to a depth of 6 ft. or more, and in the case of every sample the hygroscopic coefficient as well as the moisture content was determined, and the moisture condition is expressed as the ratio of moisture content to hygroscopic coefficient, this having the advantage of expressing the *relative moistness* while at the same time indicating whether either free water (1.1 or above) or growth water (1.6 or above) is present, and if so the amount of each.

2. The subsoils of the semi-arid prairies were characterized by their persistent dryness. Usually throughout more or less of the

first 6 ft. a ratio of 1.5 or lower was found, and commonly in one or more of the foot sections a ratio as low as 1.1 was encountered. After droughts of unusual severity the whole of the subsoil to a depth of 6 ft., and in some cases of 12 ft., showed a ratio of approximately 1.0.

3. There was no appreciable further reduction of the moisture content when, after the subsoil had been reduced to this very dry condition, there followed a 4 or 5-month period of practically rainless autumn and winter weather. After such droughts the surface foot was found but little drier than the subsoil.

4. The subsoils of the humid prairies, on the contrary, showed no distinct reduction of the moisture content through a greater depth than 5 ft., and even in this a ratio as low as 1.2 or 1.3 appeared only under the severest drought conditions. The normal moisture condition in the deeper subsoil (6–20 ft.) appears to correspond to a ratio lying between 2.0 and 2.4.

5. The dry condition of the deeper subsoil so common in the semi-arid prairies is to be attributed to the presence of perennials with a vertical root range of 15 ft. or more, while the moist condition characteristic of that of the humid prairies is regarded as evidence that the roots of the native vegetation are but little developed below the fifth foot. The occurrence of areas in the semi-arid prairies, even after a severe drought, in which the subsoil below the sixth foot is quite moist, is to be attributed to the absence or fewness of deep rooted perennials in such places.

6. After the subsoil at any level has been exhausted of the water in excess of the hygroscopic coefficient it remains in this dry condition until the precipitation conditions are sufficiently favorable to raise the ratio to 2.0 or upward throughout the whole distance from the surface down to the level in question. Accordingly during many wet periods following droughts the upper moistened portion of the subsoil will be isolated from any deeper lying moist layer by a zone in which the subsoil is too dry to permit of the penetration of plant roots.

7. While in the semi-arid prairies after protracted droughts the moisture conditions in the first 6 ft. are quite uniform, under more

normal weather conditions they vary much from place to place, thus rendering the results obtained in single borings unreliable as an index of the general moisture conditions.

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NOTES ON NORTH AMERICAN TREES. IV

C. S. SARGENT

PICEA GLAUCA (Moench) Voss, Mitt. Deutsch. Dendr. Ges. **16**:93. 1907.—Although *Abies canadensis* Miller is the oldest name for the white spruce, *Picea glauca*, according to the rules of the Vienna Congress, must be adopted for this tree, for there is a *Picea canadensis*, which is a valid name for the hemlock spruce under the genus *Picea*. The Rocky Mountain variety then becomes

PICEA GLAUCA var. **albertiana,** n. comb.—*Picea canadensis* var. *albertiana* Rehder, Mitt. Deutsch. Dendr. Ges. **24**:213. 1916.

JUNIPERUS UTAHENSIS var. **megalocarpa,** n. var.—*Juniperus megalocarpa* Sudworth, Forestry and Irrigation **13**:307. *figs. 1* and *2*. 1907; Wooton and Standley, Contrib. U.S. Nat. Herb. **19**:37. 1915.—*Sabina megalocarpa* Cockerell, Muhlenbergia **3**:143. 1907. —Differing from the type in its larger fruit sometimes 1.7 cm. in diameter, and in its habit of sometimes forming a single erect stem.

A tree 10–14 m. high, with a straight trunk occasionally 1–1.2 m. in diameter.

Valley of the San Francisco River near Alma, southwestern New Mexico, *W. R. Mattoon*, September 1906, *Alfred Rehder*, August 13 and 14, 1914 (nos. 285, 285b, 289); Arizona: rim of the Grand Canyon, *C. S. Sargent*, September 9, 1904; Angel, near Flagstaff, *Percival Lowell*, September 4, 1910.

Mr. REHDER visited the type station of this tree in New Mexico in August 1914 and obtained a large amount of material which shows that it must be considered a variety of *J. utahensis*, for he found trees with fruit intermediate in size between that of the typical *J. utahensis* (6–7 mm. in diameter) and the largest fruits of *J. megalocarpa*, that the trees with single stems did not always produce large fruit, and that the large-fruited trees sometimes had the characteristic habit of *J. utahensis*. Like that of *J. utahensis*, the fruit of the variety ripens at the end of the second season. A specimen of *J. utahensis* in the herbarium of the Arboretum collected by *E. Bethel* at Radium, Colorado, in November 1908 at an elevation of 2300 m., has fruit 1.3 cm. in diameter and should perhaps be referred to the variety.

POPULUS TREMULOIDES var. **vancouveriana,** n. var.—*Populus vancouveriana* Trelease apud Tidestrom in Piper and Beattie, Fl.

Northwest Coast, 118. 1915.—Differing from the type in its thicker, more coarsely serrate leaves, densely hoary tomentose below when they unfold, villose aments, and in its pubescent or puberulous branchlets and tomentose winter-buds. Leaves broadly ovate to semiorbicular, rounded or slightly cordate at broad base, abruptly short-pointed or rounded at apex, coarsely crenately serrate and sometimes obscurely crispate on the margins, when they unfold covered below and on the petioles with a thick coat of long matted pale hairs and slightly villose above, soon glabrous, and at maturity thick, dark green, lustrous, and scabrate on the upper surface, paler on the lower surface, 8–11 cm. long and broad, with prominent midribs and primary veins; petioles slender, compressed, becoming glabrous, 5–8 cm. in length. Rachis of the staminate inflorescence slightly villose, the pedicels pubescent; disk of the flower puberulous toward the base, flowers otherwise as in the species. Pistillate inflorescence 5–6 mm. long, the rachis, pedicels, and slightly lobed disk of the flower densely villose, becoming pubescent or glabrous on the fruit; ovary conic, pubescent, with a short style, and stigmas divided into narrow divergent lobes. Fruiting aments 8–9 cm. long, the fruit oblong-conical, pubescent or glabrous, 5 mm. long; pedicels not more than 1 mm. in length.

A tree 10–12 m. tall, with a trunk 30–40 cm. in diameter, stout spreading branches forming a round topped head, stout, reddish brown pubescent or puberulous branchlets often becoming glabrous during their first summer, and acute tomentose pubescent or glabrous winter-buds.

Borders of salt marshes on the coast of Vancouver Island, British Columbia, near Sidney, *J. Macoun*, May 3, 1913 (staminate flowers), May 13, 1913 (pistillate flowers), June 13, 1913, April 1914 (pistillate flowers), April 13, 1914 (fruit), May 6, 1914, *C. S. Sargent*, July 27, 1913; by shingle mill near Sidney, *J. Macoun*, April 2, 1913; old brickyard, Sidney, June 22, 1914; near Victoria, British Columbia, *Engelmann* and *Sargent*, August 19, 1880, *J. Macoun*, August 21, 1893 (no. 2131), May 27 and August 31, 1893 (no. 2232), May 28, 1908 (nos. 85714, 8805a), June 4, 1908 (no. 88059), May 5, 1915; Dead Man's Creek, near Victoria, *J. Macoun*, July 23, 1908; Esquimo, Vancouver Island, *J. Macoun*, June 23, 1887; Cape Laza, near Comox, Vancouver Island, *J. Macoun*, July 7, 1915.

Extreme forms of this tree certainly appear distinct from *P. tremuloides* Michaux and its western variety *aurea* Daniels, but the shape of the leaves is not constant; the branchlets and the young leaves are sometimes glabrous or nearly glabrous; on some branches the winter-buds are not tomentose but are

pubescent or glabrous; and the only constant character I can find in the Vancouver Island trees is the presence of the dense covering of hairs on the rachis of the male and female inflorescence and on the disk of the pistillate flower.

Populus arizonica, n. nom.—*Populus mexicana* Sargent, Silva N. Am. **14**:73. *pl. 733* (not Wesmael). 1902; Man. 162. *fig. 136.* 1905.—A photograph of the type specimen of *P. mexicana* Wesmael collected by *Berlandier* between Tampico and Rial del Monte in May 1827, kindly sent to the Arboretum by the late CASIMIR DECANDOLLE, shows clearly that the tree with small fruit which is common in the neighborhood of Tucson, Arizona, was wrongly referred to WESMAEL'S species. For the Arizona tree I now suggest the name of *P. arizonica.* It is well distinguished from the other cottonwoods of the United States by the small fruit, which does not exceed 5 mm. in length.

ARIZONA.—Common up to 2200 m. above sea level. Santa Catalina Mountains, Pima County, *C. G. Pringle,* 1881, *A. Rehder,* August 8, 1914 (no. 256); Bear Creek, foot of Santa Catalina Mountains, *A. Rehder,* August 30, 1916 (no. 452); Sabino Canyon, Santa Catalina Mountains, *J. W. Toumey,* February 20, 1894, *A. Rehder,* August 7, 1914 (no. 233), September 1, 1916 (no. 500); near Tucson, Pima County, *Engelmann* and *Sargent,* September 30, 1880, *J. W. Toumey,* February 27, 1894, February 1898, *C. S. Sargent,* February 27, 1894, March 27, 1916; Douglas, Cochise County, *A. Rehder,* August 27, 1916 (no. 447a, a planted street tree); Yavapai County, near Clarkdale, *A. Rehder,* September 11, 1916 (no. 555), near Camp Verde, September 9, 1916 (no. 542), Beaver Creek, near Camp Verde, September 8, 1916 (no. 540), banks of Gannett Creek, Prescott, September 4, 1916; on Salt River, near the Roosevelt Dam, Gila County, *W. H. Goddard,* June 1917; Coconino County, Sycamore Canyon, *Percival Lowell,* September 1915, *A. Rehder,* September 14, 1916 (no. 573); Hermit Creek, Grand Canyon of the Colorado, *Alice Eastwood,* April 10, 1917 (no. 6002); Turkey Creek, near Flagstaff, *C. O. Lampland,* March 1917; Canyon Diablo, *C. O. Lampland,* April 5, 1915 (these specimens have only very young flower buds and may belong to another species).

CALIFORNIA.—A sterile branch collected by *A. Rehder* July 23, 1914 (no. 128), on Mill Creek above Forest Home, San Bernardino Mountains, is doubtfully referred to this species.

NEW MEXICO.—Near Silver City, Grant County, *E. L. Greene,* 1880 (distributed as *P. Fremontii*), *O. F. Arthur,* March 16, 1918, *M. W. Talbot,* April 1, 1918, *J. A. Scott,* May 18, 1918.

In the neighborhood of Tucson, where this poplar has been planted in considerable numbers, it is a magnificent tree 20–28 m. in height with a trunk

sometimes 1 m. in diameter, a broad head of wide spreading branches, slender branchlets, glabrous or puberulous, and lustrous yellow-green leaves often puberulous early in the season. The bark of the branches and young stems is nearly white and on old trunks it is pale green and slightly divided into broad flat ridges.

POPULUS ARIZONICA var. **Jonesii,** n. var.—Differing from the type in the pubescent, not puberulous, young leaves, petioles, and young branchlets.

Mexico, Valley of Palms, *Marcus E. Jones*, April 8, 1882 (no. 373, type); valley near Chihuahua, *C. G. Pringle*, March 31, 1886 (no. 885); Saltillo, *C. G. Pringle*, June 4, 1888 (no. 2098, with larger leaves and more pubescent branchlets), *C. S. Sargent*, March 1887 (a very large tree with pendulous branches); Valley of Mexico, *C. G. Pringle*, February 13, 1899 (no. 8019); Pedras Negras, *C. S. Sargent*, March 21, 1900 (a planted tree).

Populus Palmeri, n. sp.—Leaves thin, ovate, cuneate or rounded at the broad base, gradually or abruptly contracted at apex into a narrow acuminate entire point, finely serrate with incurved teeth, ciliate on the margins when they unfold, otherwise glabrous, 6–10 cm. long and 4.5–8 cm. wide; petioles slender, glabrous, 3.5–6 cm. in length. Flowers not seen. Fruit in slender glabrous aments 12–15 cm. long, ovate, obtuse, slightly pitted, puberulous, thin-walled, 4-valved, 6–7 mm. long, the disk deeply lobed, 4–5 mm. in diameter; pedicels slender, 7–9 mm. in length.

A tree 20–21 m. tall with a straight trunk 1 m. in diameter, erect, smooth, pale branches forming an open pyramidal head, the lower branches smaller, horizontal or pendulous, and slender, glabrous branchlets light reddish brown early in the season, becoming pale grayish brown in their second year. Bark pale, 5 cm. thick, deeply divided by wide fissures into narrow ridges.

In most fertile soil near springs, at the base of high chalk bluffs of Nueces Canyon of the upper Nueces River, Uvalde County, Texas, growing with *Salix nigra* var. *Lindheimerii*, *Carya pecan*, *Morus rubra*, and *Ulmus crassifolia*, *E. J. Palmer*, April 11 and September 1918 (nos. 13340, 14511).

In the shape of the leaves and their serration, in the small fruit, and in the remarkably slender branchlets this poplar is so different from all other American species that, although it is still very imperfectly known, I venture to describe it. It is the only species seen by PALMER in Uvalde County.

Populus texana, n. sp.—Leaves thin, glabrous, broadly ovate, truncate at base, gradually narrowed, long-pointed, acuminate at apex, coarsely crenately serrate below the middle, entire above,

7–8 cm. long and 6–7 cm. wide; petioles slender, compressed, 4–7 cm. in length. Flowers not seen. Fruit in slender, glabrous aments 7–8 cm. long, oblong-ovate, acute, deeply pitted, glabrous, thin-walled, 3-valved, 8–9 mm. long, the disk slightly lobed, 2.5–3 mm. in diameter; pedicels slender, 3–4 cm. in length. Seeds ovate, acuminate, 4 mm. long.

A tree up to 20 m. high, with a trunk sometimes 1 m. in diameter, and stout more or less pendulous branches, stout, glabrous, pale yellow-brown branchlets, and acuminate, glabrous winter-buds.

In canyons and along the streams of northwestern Texas, where it appears to be the only cottonwood. Low sandy banks of the Canadian River, Canadian, Hemphill County, *E. J. Palmer*, June 17, 1918 (no. 14107); creek banks, Amarillo, Potter County, *E. J. Palmer*, July 13, 1917 (no. 12541); canyon, Paloduro Creek, Randall County, *E. J. Palmer*, October 3, 1918 (no. 14591); river banks in canyon, Gamble's Ranch, Armstrong County, June 6, 1918 (no. 13959). "One of the largest trees found in Paloduro Canyon, growing in the protection of high bluffs. It usually grows in the protection of high bluffs or at the heads of canyons. The young trees here are slender and straight, but older specimens are very irregular or unsymmetrical in growth, with pale or dark ashy bark. It is rarely found in the more open parts of the canyon here, but near Canyon City it grows on the river margins" (E. J. P. in litt.); Post, Garza County, *E. J. Palmer*, May 31, October 1, 1918 (nos. 13848, 13853, 14575); along creeks, Sweet Water, Nolan County, *E. J. Palmer*, October 21, 1917, May 28, September 28, 1918 (nos. 13045, 13799 type, 13899, 14526).

By the shape of the leaves and by the thickness and color of the branchlets this species cannot be distinguished from *P. Wislizenii* Sargent, but from that species it is well distinguished by the smaller fruit on much shorter pedicels and by the glabrous winter-buds. The range of the two trees is also quite different.

POPULUS MACDOUGALLII Rose, Smithsonian Misc. Coll. **61**:61. 1913.—This species, of which I have not seen the flowers, is well distinguished from *P. Fremontii* by the minute disk of the fruit, which does not exceed 3 mm. in diameter. The fruit is borne on slender, glabrous pedicels 3–5 mm. in length, in racemes 5–6 cm. long; it is ovate and acute at apex to ellipsoidal and acute or acuminate at ends, glabrous, slightly pitted, thin-walled, 3-valved, 10–12 mm. in length. The seed is oblong-ovate, acuminate, 3 mm. in length.

It is probably always a small tree with erect branches and slender branchlets pubescent or puberulous when they first appear, soon becoming glabrous and pale yellow-brown at the end of their first season.

This is the common and probably the only cottonwood of the valley of the lower Colorado River. It is common on both banks of the river at Yuma, and is planted in some of the towns of the Colorado Desert region like Yuma, Mecca, and Indio. It has also been planted at the Needles on the Colorado River in San Bernardino County, California.

POPULUS FREMONTII S. Watson.—This is the common and only cottonwood of the valleys of northern and central California west of the Sierra Nevada. The leaves are slightly cordate at the broad base and coarsely serrate often with few teeth. The fruit is ovate with a disk about 5 mm. in diameter, on pedicels 3–5 mm. in length.

In San Bernardino County, California, Nevada, Utah, and Arizona poplar trees occur which, although the disk of the fruit is smaller or larger than that of the typical *P. Fremontii*, until better known are best considered perhaps varieties of that species. Three of these forms may be distinguished as follows:

POPULUS FREMONTII var. **Thornberii,** n. var.—Leaves broadly ovate, abruptly contracted into acuminate points, slightly cordate at the wide base, coarsely crenately serrate with numerous teeth, glabrous, 6–8 cm. long and broad; petioles 3.5–4 cm. in length. Flowers not seen. Fruiting aments 5–6 cm. long, the capsules ellipsoidal, 3-valved, deeply pitted, 8–9 mm. long; disk 3 mm. in diameter; pedicels 2–3 mm. in length.

A large tree with pale deeply furrowed bark and pale gray glabrous branchlets.

Low ground near Tucson, Pima County, Arizona, *C. S. Sargent*, March 27, 1916.

From the typical *P. Fremontii* this variety differs in the more numerous serratures of the leaves, in the ellipsoidal, not ovate, fruit with a smaller disk, and in the much shorter pedicels. This tree was shown to me by Professor J. J. THORNBER of the University of Arizona, whose name I venture to associate with it.

POPULUS FREMONTII var. **pubescens,** n. var.—Differing from the type in its more pubescent branchlets.

This is a common tree in San Bernardino and San Diego counties, California, and extends into Nevada and southern Utah. The branchlets of the type specimen of *P. Fremontii*, which was collected by *Fremont* in the upper Sacramento Valley, are described as slightly pubescent, but on the other specimens of this tree which I have seen from California north of San Bernardino County they are glabrous, and as the range of the trees with the

distinctly pubescent branchlets extends far beyond the region occupied by typical *P. Fremontii* it will perhaps be best to consider that they represent a geographical variety. I have seen the following specimens:

CALIFORNIA.—San Bernardino Mountains, *G. R. Vasey*, 1880; San Bernardino, *C. C. Parry*, April 1883, *C. S. Sargent*, March 30, 1916; Barstow, San Bernardino County, *W. L. Jepson*, May 1914 (no. 5894), March 8 and 22, 1916 (nos. 6610, 6611, 6626); Warner Hot Springs, San Diego County, *Alice Eastwood*, April 9, 1913 (no. 2619); Bernardo, San Diego County, *Le Roy Abrams*, May 2, 1903 (no. 33701).

NEVADA.—"Kiernan, Meadow Valley, Wash.," *L. N. Goodding*, April 28, 1902 (no. 634); south base of Mount Grant, Mineral County, *A. A. Heller*, July 2, 1913 (no. 10909).

UTAH.—St. George, Washington County, *M. E. Jones*, March 30, 1880 (no. 1611).

POPULUS FREMONTII var. **Toumeyi**, n. var.—Differing from the type in the cordate-cuneate broad base of the leaves, and in the larger disk of the fruit. Leaves ovate, the base shallow cordate and gradually narrowed and cuneate to the insertion of the petiole, gradually narrowed and acuminate at the entire apex, coarsely and irregularly crenately serrate below, glabrous, 6–7 cm. long and broad. Fruit oblong-ovoid to slightly obovoid, acute or obtuse at apex, 8–10 mm. long, the disk 6–7 mm. in diameter; pedicels 4–5 mm. in length.

ARIZONA.—Tucson, Pima County, *J. W. Toumey*, April 28, 1894 (type); Pima Canyon, Santa Catalina Mountains, Pima County, *J. J. Thornber*, March 2, 1913; Santa Cruz River bottoms, Pima County, *J. J. Thornber*, March 30, 1913; Nogales, Santa Cruz County, *McPherson*, April 15, 1915; Hermit Creek, Grand Canyon of the Colorado, Coconino County, *Alice Eastwood*, April 10, 1917 (no. 6002).

Populus Parryi, n. hyb. (*P. Fremontii*×*trichocarpa*).—Leaves ovate, rounded or slightly cordate at the broad entire base, gradually narrowed, acuminate and entire at apex, finely crenately serrate below, sparingly villose and ciliate on the margins when they unfold, soon glabrous, and at maturity thin, dark green, and lustrous above, silvery white below, 6–8 cm. long and broad; petioles slender, slightly compressed, glabrous, 4–6 cm. in length; leaves on vigorous shoots sometimes oblong-ovate, truncate or rounded at base, acute at apex, more coarsely serrate, 9–12 cm. long and 8–10 cm. wide, with stout compressed petioles 3–4 cm. in length.

Staminate aments densely flowered, 5–6 cm. long, puberulous, the bract of the flower broadly obovate, laciniate; anthers 10 or 12; aments of pistillate flowers villose, 6–7 cm. long, becoming at maturity 15–16 cm. in length. Disk of the flower broad, entire or erose on the margin; ovary broad, ovate, puberulous; stigma 3-lobed or occasionally 2-lobed. Fruit broadly ovate, rounded at apex, slightly pitted, puberulous, thin-walled, inclosed sometimes for one-third of its length in the enlarged disk, 5–6 mm. long, often abortive; pedicels puberulous, 2–2.5 mm. in length; seeds narrow-obovoid to ellipsoidal, 3 mm. long.

A large tree with deeply furrowed bark, wide spreading branches, slender glabrous branchlets reddish brown in their first season, light orange-brown in their second year, and acuminate, lustrous, glabrous winter-buds.

Streets of San Bernardino, San Bernardino County, California, *C. C. Parry*, March and April 1883 (type), *C. S. Sargent*, March 16, 1916, *S. B. Parish*, October 15, 1917; along Cottonwood Creek, west side of Owen's Lake, Inyo County, California, *F. V. Coville* and *F. Funston*, June 19, 1881 (no. 996); in the Canoda de las Uvas, about 2 miles north of Fort Tjon, Kern County, California, *F. V. Coville* and *F. Funston*, July 5, 1891 (no. 1163).

These trees appear intermediate in character between *P. Fremontii* and *P. trichocarpa*. The leaves resemble in shape those of the common Californian form of *P. Fremontii*, but are silvery white below like those of *P. trichocarpa* and the other balsam poplars, and their serration is much finer than that of the leaves of *P. Fremontii*, but coarser than that of the leaves of *P. trichocarpa*. The staminate flowers have fewer stamens than those of either of the supposed parents; the disk of the female flowers is very similar to that of both of them, but the ovary, which is glabrous in *P. Fremontii* and densely tomentose in *P. trichocarpa*, is pubescent. PARRY, who first noticed this tree and who would have considered it a new species if he had seen it growing wild, thought that it might have been an exotic species introduced into San Bernardino. The leaves on the specimens of the wild plants from the western base of the Sierra Nevada are similar to those of the San Bernardino trees, but the fruit is rather longer and more acute. Of these specimens COVILLE wrote me November 4, 1892: "I send you by mail specimens of a poplar collected along streams flowing from the southern Sierra Nevada. Specimens of *P. Fremontii*, *P. tremuloides*, and *P. trichocarpa* were collected by the Expedition (Death Valley), and these specimens show characters between *P. Fremontii* and *P. trichocarpa*."

OSTRYA VIRGINIANA K. Koch.—The variety of this tree, on which the branchlets, petioles, and peduncles are covered with short erect glandular hairs, may be distinguished as

OSTRYA VIRGINIANA var. **glandulosa,** n. comb.—*Ostrya virginiana* var. *glandulosa* Spach, Ann. Sci. Nat. II. **16**:246. 1841.

From Quebec and Ontario to southwestern New England and western New York, and in eastern Michigan this is the prevailing variety. The two forms occur in New Jersey, Pennsylvania, Indiana, northern Illinois, southwestern Missouri, Oklahoma, and on the high Appalachian Mountains.

Betula Eastwoodae, n. sp.—Leaves broad-ovate to elliptic, crenately serrate except at the cuneate base, thick, glabrous, dark green above, pale below, rather conspicuously reticulate venulose especially on the upper side, 2.5–3 cm. long and 1.6–2.3 cm. wide; petioles slender, glabrous, often tinged with red, 5–7 mm. in length. Staminate catkins usually solitary or in pairs, sessile, 2–3 cm. long, 5 mm. in diameter, their scales broadly ovate, acute and apiculate at apex, pubescent, dark red. Pistillate catkins pendulous on peduncles 8–10 mm. long, cylindric, 1.5–2 cm. in length, 6–7 mm. in diameter, their scales longer than broad, the lobes rounded at the narrow apex, ciliate, the lateral slightly spreading, one-third shorter than the terminal lobe.

A tree rarely more than 6–7 m. tall with a trunk not more than 15 cm. in diameter, covered with close chestnut brown lustrous bark about 5 mm. thick and marked by conspicuous horizontal white lenticels, and slender red branchlets more or less thickly covered with circular white glands.

Roadsides, Hunker Creek, Yukon District, *J. Macoun,* August 4, 1902 (no. 54412); swamps in the town of Dawson, valley of the Yukon, British Alaska, forming jungles with *Betula glandulosa* Michaux, occasional plants of *Betula alaskana* Sargent, and different willows, *Alice Eastwood,* May 22 and June 14, 1914 (nos. 88, 271=88 type, also nos. 6, 7, 58, 69, 533=69, 89, 272–89, 102, 282, 381).

The relationship of this tree is with *B. glandulosa* Michx., from which it differs in the shape and venation of the leaves, in the pendulous fruiting catkins, and in its arborescent habit.

Betula commixta, n. hyb.? (*B. alaskana*×*glandulosa?*).—Leaves broadly ovate to elliptic, acute at apex, broad-cuneate or rounded at base, coarsely serrate with blunt or acute teeth, thin, glabrous, smooth, dark green and lustrous above, pale and lustrous below, 3–4.5 cm. long and broad; petioles 1.5 cm. in length. Flowers not seen. Fruiting catkins erect, 2 cm. long, 6–7 mm. in

diameter, their scales puberulous, the terminal lobe acute, one-third longer than the rounded lateral lobes.

A shrub 2–3 m. tall, with dark brown stems and slender gray-brown branchlets thickly covered with resinous glands.

On the tundra with *B. glandulosa* in the neighborhood of Dawson, British Alaska, *Alice Eastwood*, Ten Mile House, June 25, 1914 (no. 367 type); Twenty-four Mile House, June 27, 1914 (no. 400).

The proper disposition of this plant is doubtful, and it should perhaps be considered a species. The glandular branchlets and slender erect fruiting catkins resemble those of *B. glandulosa* Michaux, but the larger, acute, sharply serrate leaves are not of that species, and if it is a hybrid the size and serration of the leaves can only have been derived from *B. alaskana* Sargent.

CELTIS OCCIDENTALIS L.—On what is usually considered the type of this species the leaves are broadly ovate, acute or short-acuminate at apex, obliquely rounded at base, coarsely or finely serrate, smooth on the upper surface, glabrous or sparingly pilose along the midribs and veins below, thin, not conspicuously venulose; petioles glabrous or rarely puberulous. The fruit is borne on glabrous or rarely puberulous pedicels much longer than the petioles and is subglobose, ellipsoidal, or slightly obovoid, and 9–10 mm. in diameter; the stone is only slightly reticulate. The branchlets are glabrous or occasionally pubescent.

C. occidentalis is distributed from New England to Virginia and westward to Iowa, southwestern Missouri, western and central Kansas, and eastern North Dakota. It is less common and usually a smaller tree than its varieties *canina* and *crassifolia*, and much less widely distributed than the latter. All the forms of *C. occidentalis* are well distinguished by the dark purple fruit, which is larger than that of the other American species; it is borne on longer pedicels than that of our other species, with the exception of that of *C. Douglasii*.

CELTIS OCCIDENTALIS var. **canina,** n. var.—*C. canina* Rafinesque, Am. Monthly Mag. **2**:43. 1817; Planchon, DeCandolle Prodr. **17**:174. 1873; Britton and Shafer, N. Am. Trees, 355. 1908.—*C. occidentalis* Sargent, Silva N. Am. **7**:67 (in part, *pl. 317*, not Linnaeus). 1895; Hough, Trees N. States and Canada, 193 (in part, *fig. 217*). 1907.—Differing from the type in the usually narrower long-acuminate leaves.

Extreme forms of this variety look very distinct, but trees with leaves intermediate between these and those of the typical form are common. The

fruit varies as in the type from subglobose to obovoid, and there seems little difference in the length of the pedicels, which are always longer than the petioles. The leaves are usually glabrous, but on some of *Bush's* Missouri specimens the midribs and veins are pilose on the lower surface and the petioles are pubescent, as in the variety *crassifolia* (Monteer, nos. 548, 4725; Christian County, no. 4664; Dumas, no. 5905). This variety is distributed from the Province of Quebec to Iowa, Nebraska, North Dakota, and southwestern Missouri, southwestern Oklahoma, New York, and Ohio, and to northwestern Georgia (Cobb County, *R. M. Harper*, no. 166 in Herb. Gray). More distinct is

CELTIS OCCIDENTALIS var. CRASSIFOLIA Gray, Man. ed. 2, 397. 1856.—*C. crassifolia* Lamarck, Encycl. Méth. 4:138. 1797.—Differing from the type in its usually narrower, acuminate, thicker leaves, often more coarsely serrate or nearly entire, scabrate on the upper surface and pilose below along the midribs and veins.

In this form the petioles are usually villose-pubescent, but occasionally are quite glabrous; the pedicels are slightly villose, and the branchlets are glabrous or pubescent.

I have seen specimens of this variety from Viriginia and West Virginia; North Carolina, *A. Gray*, Painted Rock, French Broad River, 1843 (in Herb. Gray); river banks, Biltmore (ex herb. Biltmore no. 1210, with nearly entire leaves); Nashville, Tennessee; southern Indiana, wooded bluff of Blue River, near Middletown, Crawford County, *C. C. Deam*, June 15, 1915 (no. 16423, with coarsely serrate leaves, "a flat-topped shrub about 8 ft. high"), June 25, 1915 (no. 16418, the leaves entire or furnished with occasional teeth, "a shrub 8 ft. high in the dense shade of walnut and buckeye trees"); wooded bluff of the Ohio River, 6 miles east of Cannelton, Perry County, *C. C. Deam*, June 29, 1915 (no. 16627, a tree 8 m. high with nearly entire leaves); southern and western Illinois; Fort Snelling, Minnesota; northern and southern Missouri; central Kansas; eastern and northwestern Oklahoma; Thomas County, central Nebraska; Bigstone, eastern South Dakota; central North Dakota; from the Tongue River Canyon, Big Horn Mountain, Wyoming; from the Black Canyon of the Boise River and the valley of the Clearwater River, Nez Perce County, Idaho; from Berlin, Dallas County, Alabama, *R. S. Cocks*, 1913 (with nearly entire leaves), and from Larissa, Cherokee County, *B. F. Bush*, April 30, 1909 (no. 5561); and Livingston, Polk County, Texas, *E. J. Palmer*, October 9, 1914 (no. 6785).

CELTIS DOUGLASII Planchon, Ann. Sci. Nat. III. 10:293. 1848; Piper, Contrib. U.S. Nat. Herb. 2:221 (Fl. Washington). 1906; Britton and Shafer, N. Am. Trees, 359. *fig. 319.* 1908.—*C. reticulata* Howells, Fl. N.W. America 602 (not Torrey). 1897.—*C. rugosa*

Rydberg, Bull. Torr. Bot. Club **39**:304 (not Newberry). 1912.—*C. rugulosa* Rydberg, Fl. Rocky Mountains, 207. 1061. 1917.—This tree, which has sometimes been considered the same as the more southern *C. reticulata* Torrey, can be distinguished from that species by its rather thinner, oblong-ovate, long-acuminate, coarsely serrate leaves, cordate or obliquely cordate at base, glaucescent on the lower surface and glabrous or sparingly pilose on the under side of the midribs and veins, by the slightly pilose petioles, and by the much longer pedicels of the fruit sometimes up to 1.5 cm. in length. The fruit, which has been described as "black or brownish," is light orange-brown on the Oregon and Colorado trees, and is subglobose to ellipsoidal and 7–8 mm. in diameter.

C. Douglasii is a shrub or a small tree rarely 10 m. high, with rough, red-brown, or in Colorado dark gray bark 2.5 cm. thick and irregularly ridged, glabrous or slightly pilose branchlets, and pubescent and tomentose winter-buds.

Nowhere common, it is widely distributed on dry ridges and the rocky banks of streams, and occurs in Oregon east of the Cascade Range in the valley of the Deschutes River, on the rocky banks of the Columbia near the Dalles and on Pine Creek, Gilliam County, and in western Washington ranges from the valley of the Columbia in Klickitat County to the rocky banks of Snake River in Whitman County, and to Big Willow Creek, Canyon County, Idaho; it inhabits the western foothills of the Wasatch Mountains of Utah, south-eastern Utah (Grand River Canyon below Moab, Grand County), the southern slope of the Grand Canyon, Arizona (*A. Rehder*, July 19, 1914, no. 103), "in sand at the mouth of a dry canyon one-half mile below Democrat Springs, Kern River," Kern County, California, *Mrs. Leo Polkingham*, September 1916 (in Herb. Dudley), and on the eastern foothills of the Rocky Mountains of Colorado.

In the shape of the coarsely serrate leaves and in the long pedicels of the fruit *C. Douglasii* is related to *C. occidentalis* var. *crassifolia*, from which it differs in its thicker leaves with conspicuous reticulate veinlets and usually glaucescent and less pubescent on the lower surface, and in the color of the fruit. In the thick reticulate-venulose leaves rough on the upper surface it resembles *C. reticulata*. Geographically *C. Douglasii* is intermediate between *C. occidentalis*, which in its var. *crassifolia* reaches northern Idaho, and *C. reticulata*, which extends northward to the Grand Canyon in Arizona.

CELTIS LINDHEIMERII K. Koch apud Engelmann, Dendr. **2**:434. 1872.—*C. Helleri* Small, Bull. Torr. Bot. Club **24**:439. 1897;

Britton and Shafer, N. Am. Trees 358. *fig. 318.* 1908; Mackensen, Trees and Shrubs of San Antonio, 17. *pl. 3.* 1909.—KOCH's description of *C. Lindheimerii* was made from a tree growing in the Botanic Garden in Berlin which had been raised from seeds gathered at New Braunfels, Texas, by LINDHEIMER and sent by ENGELMANN to Berlin. KOCH's description leaves no doubt that *C. Lindheimerii* (Engelmann in Herb. A. Braun) is the tree with leaves pale and densely pubescent on the lower surface and pubescent branchlets which is common at New Braunfels and in the neighborhood of San Antonio.

Of the specimens of this tree which I have seen the oldest was collected by *Drummond* in 1834 without locality but probably near Austin (nos. 343?, 334, 259 in Herb. Gray). It was collected by *Lindheimer* at New Braunfels, Comal County, in 1850 (no. 444 in Herb. Gray). *Mohr* collected it in the valley of the Comal River, New Braunfels, in 1850. I collected it at San Antonio, Bexar County, in 1881, and *Bush* also collected it at San Antonio October 1900 (no. 1246), September 1901 (no. 797), and March 1902 and 1903 (nos. 1172, 3677). *Palmer's* collections of this tree are from Sutherland Springs, Wilson County (no. 9302), Goliad, Goliad County (no. 9128), San Marcos, Hays County (no. 13311), dry limestone banks, South Llano River, Telegraph, Kimble County (no. 10931).

C. Lindheimerii is most abundant in the neighborhood of streams and springs and occurs less commonly on higher ground. I have no evidence that it grows on the Edwards Plateau or westward.

CELTIS RETICULATA Torrey, Ann. Lyc. N.Y. **2**:247. 1828; Planchon, Ann. Sci. Nat. III. **10**:293. 1848.—*C. occidentalis* var. *reticulata* Sargent, Forest Trees N. Am. 10th Census U.S. **9**:126. 1884; Garden and Forest **3**:40. *fig. 12.* 1890.—*C. mississippiensis* var. *reticulata* Sargent, Silva N. Am. **7**:72 (in part). 1895; Man. 301. *fig. 243.* 1905.—*C. reticulata*, *C. Lindheimerii*, and *C. Douglasii* are similar in their thick leaves, rough on the upper surface and conspicuously reticulate venulose below, and in their pedicels longer than the petioles. The entire leaves green on the lower surface and the orange-red fruit on shorter pedicels of *C. reticulata* distinguish it from *C. Douglasii*. The shape of the leaves of *C. Lindheimerii*, pale and pubescent below over their whole surface, makes it easy to distinguish that species from *C. reticulata*.

I have not seen the flowers and spring leaves of *C. reticulata*, which, although it was described 90 years ago, is still very imperfectly known. The young

leaves, like those of the other species of this group, probably show little evidence of the prominent veinlets which are not conspicuous on them before early summer. In collections of Texas plants *C. Lindheimerii* and more frequently *C. laevigata* var. *texana* have been confounded with *C. reticulata*.

Seedlings raised at the Arboretum from seeds of a tree with rough, mostly entire leaves growing at the Montezuma Well in central Arizona (*Rehder*, no. 537) have coarsely serrate leaves which are rough or nearly smooth above on the same branchlet.

From western Texas I have seen specimens of *C. reticulata* collected in Uvalde, Kimble, Mitchell, Nolan, Callahan, Randall, Hartley, and Jeff Davis counties. It ranges into western Oklahoma, and through southern New Mexico to southern, central, and northeastern Arizona, and occurs on Cedros Island off the coast of Lower California (*Veatch*, 1872, in Herb. Gray).

CELTIS RETICULATA var. **vestita,** n. var.—Differing from the type in its more pubescent serrate leaves and more pubescent petioles. Leaves broadly ovate, acute or acuminate at apex, unsymmetrically rounded or subcordate at base, the margins thickened, ciliate, and sharply but irregularly serrate, thick, dark green and scabrate above, paler and coated below with short pale pubescence with longer hairs on the slender midribs, primary veins, and conspicuoulsy reticulate veinlets, 3.5–4.5 cm. long and 3–3.5 cm. wide; petioles densely tomentose, 4–5 mm. in length; leaves on vigorous shoots acuminate, mostly cordate at base, more coarsely serrate, rugose, and covered above with short white hairs and more densely pubescent below, 6–8 cm. long and 4–4.5 cm. wide, their petioles thickly covered with matted pale hairs, 8–9 mm. in length. Fruit orange-red, 6–7 mm. in diameter.

A small tree with a trunk 20–25 cm. in diameter and slender pubescent branchlets, those of vigorous shoots stouter and densely villose.

Near Canton, Blaine County, Oklahoma, in low ground along the North Fork of the Canadian River, *D. M. Andrews*, August 15, 1915 (nos. 21, 49 type).

Specimens of vigorous sterile branches collected by *Palmer* at Canadian, Hemphill County, Texas, June 17, 1918 (no. 14109), may prove a distinct form of this variety. The leaves are acuminate, obliquely cordate at base, coarsely serrate, more pubescent below, 6–9 cm. long and 3.5–5 cm. wide; the petioles and branchlets are densely tomentose.

CELTIS LAEVIGATA Willdenow, Berl. Baum. ed. 2. 81. 1811.—*C. mississippiensis* Bosc in Encycl. Mét. Agric. **7**:577 (*nomen nudum*). 1821; Spach, Ann. Sci. Nat. II. **16**:42. 1841.—*C. Berlandierii* Klotzsch, Linnaea **20**:541. 1847; Parlatore, DeCandolle

Prodr. 17:178 (in part). 1873.—For this tree of the southern states the name *C. mississippiensis* has usually been adopted. Bosc published a brief account, without a name or technical description, of Le Microcoulier de la Louisiana cultivated in France in the *Nouveau Cours Complet d'Agriculture* (8:529. 1809), and republished it in the second edition of this work (10:41. 1822). As his plant came from near the mouth of the Mississippi River there is little doubt of its identity with the *C. mississippiensis* of SPACH, for it was SPACH who first described this tree as *C. mississippiensis*, BOSC's earlier *C. mississippiensis* being a *nomen nudum* and 10 years later than *C. laevigata* of WILLDENOW which, following K. KOCH, must be taken up for our tree. A cotype of *C. Berlandierii* Klotzsch (no. 2318), collected by *Berlandier* at "Matamoras de Tamaulipas," April 1831, is preserved in the Gray Herbarium on a sheet with *Berlandier's* no. 885, also collected at Matamoras in April 1831. A fragmentary specimen with flowers, collected by *Berlandier* in February 1828 (no. 1487–2271), a fruiting branch without locality or date and numbered 2429 on a label printed for the Gray Herbarium, and a vigorous shoot (no. 2429–999), collected by *Berlandier*, May 1824, "De Goliad à Bexa," are mounted on another sheet. The leaves and fruit of these *Berlandier* specimens only differ in their smaller size from specimens of the leaves and fruit of *C. laevigata* grown on the rich bottom lands of the Mississippi Valley, a difference which the dryness of the region where *Berlandier* collected them explains.

C. laevigata, when it grows under favorable conditions, is a tree sometimes 30 m. high, with somewhat pendulous branches and slender, glabrous, red-brown branchlets. The leaves are thin, usually oblong-lanceolate, long-pointed and acuminate at apex, unsymmetrically rounded and often oblique or cuneate at base, frequently more or less falcate, entire or furnished with a few teeth usually toward the apex, green on both surfaces, glabrous, smooth or occasionally scabrate above. The fruit is bright orange-red on pedicels shorter or slightly longer than the petioles.

C. laevigata is distributed from the coast of Virginia to the Everglade Keys of southern Florida and through the Gulf states to the valley of the lower Rio Grande in Nuovo Leon, Mexico, and through eastern Texas and Arkansas to

eastern Oklahoma and Kansas, northern Missouri, southern Illinois, and southwestern Indiana; also in Bermuda. Trees occasionally occur with leaves more or less sharply serrate nearly to the base, and this variety may be distinguished as

CELTIS LAEVIGATA var. **Smallii,** n. var.—*C. Smallii* Beadle, Small Fl. S. United States, 365. 1329. 1903.—Differing from the type only in its constantly serrate leaves.

CELTIS LAEVIGATA var. **texana,** n. var.—*C. texana* Scheele, Linnaea **22**:146. 1847.—*C. Berlandierii* Planchon, DeCandolle Prodr. **17**:178 (in part, not Klotzsch). 1873.—Differing from the type in the shorter ovate to lanceolate thicker leaves often pubescent on the midribs and veins below, in the often more prominent veinlets and pubescent petioles, and in its often pubescent branchlets. Leaves ovate to lanceolate, acuminate, unsymmetrically rounded or cordate at base, entire or sparingly and irregularly serrate, often subcoriaceous, dark green, smooth and granulate or rarely scabrate above, green below, with slender midribs and primary veins glabrous or sparingly villose-pubescent and furnished with small axillary tufts of pale hairs, and thin, only slightly raised, reticulate veinlets, 3.5–7 cm. long and 2–3.5 cm. wide; petioles slender, pale pubescent, 5–7 mm. in length. Flowers not seen. Fruit subglobose but rather longer than broad, dark orange-red, 6–7 mm. in length; pedicels glabrous or puberulous, slightly longer than the petioles.

An arborescent shrub or small tree rarely more than 8 m. high, often growing in groups, with pale or grayish rough bark rarely covered with wartlike excrescences, and slender, reddish, glabrous or gray-brown, pubescent branchlets.

I have taken up SCHEELE's name for the common *Celtis* of the Edwards Plateau and western Texas with some hesitation, for I have not seen his type specimen. His description perfectly applies, however, to a specimen collected by *Lindheimer* at New Braunfels in the herbarium of the Arboretum (no. 4 ex herb. Engelmann as *C. texana*). On other specimens collected by *Lindheimer* at New Braunfels the lower side of the midribs and veins of the leaves are sparingly villose-pubescent, and such pubescence is found on the leaves of most of the specimens which I have referred to this variety.

TEXAS.—New Braunfels, Comal County, *F. Lindheimer,* 1850 (nos. 1158, 1159 in Herb. Gray, distributed by the Mo. Bot. Gard. as *C. Berlandierii*); no. 4 (in Herb. Arnold Arboretum ex Herb. Engelmann, type); Comanche

Spring, New Braunfels, *C. Mohr*, December 1880; San Antonio, Bexar County, *B. F. Bush*, October 2, 1900 (no. 1223), September 16, 1901 (no. 807), March 23, 1902 (no. 1174), *B. Mackensen*, October and December 1910; Sutherland Springs, Wilson County, *E. J. Palmer*, March 30, 1916 (no. 9297); Pleasanton, Atascosa County, *E. J. Palmer*, September 23, 1916 (no. 10773); rocky river banks, Blanco, Blanco County, April 6, 1918 (no. 13294), *Berlandier* "entre le rio de las Nueces et Laredo," June 1820 (nos. 601, 2011 in Herb. Gray); Boerne, Kendall County, *E. J. Palmer*, May 18, 1918 (no. 13644, with hoary tomentose branchlets); Kerrville, Kerr County, *B. Mackensen*, May 1, 1910; Uvalde, Uvalde County, *E. J. Palmer*, April 10 and May 6, 1918 (nos. 13324, 13509, with coarsely serrate leaves scabrate on the upper surface); Sweet Water, Nolan County, *E. J. Palmer*, July 6, 1917 (nos. 12432, 12433); Barksdale, Edwards County, *E. J. Palmer*, May 7, 1918 (no. 13519); banks of Devil's River, Valverde County, *E. J. Palmer*, May 14, 1918 (no. 13601); Limpia Canyon, Jeff Davis County, *Tracy* and *Earl*, April 25, 1902 (no. 238 in Herb. Gray); Post, Garza County, *E. J. Palmer*, May 31, October 1, 1918 (nos. 13837, 14565); banks Canadian River, Canadian, Hemphill County, *E. J. Palmer*, June 17, 1918 (no. 14110); Strawn, Palo Pinto County, *E. J. Palmer*, June 27, 1918 (no. 14256); Gamble's Ranch, Armstrong County, June 6, 1918 (no. 13969); along the Brazos, Graham, Young County, *J. Reverchon*, October 27, 1902 (nos. 3262, 3267); dry rocky hillsides, Baird, Callahan County, *E. J. Palmer*, May 26, 1918 (no. 13680); Paloduro Canyon, Potter County, *J. Reverchon*, May 22, 30, 31, 1902 (nos. 3265, 32 f. f. 2930, 2930 bis), *E. J. Palmer*, June 3, 1918 (no. 13866), *C. S. Sargent*, April 1916; Tivoli, Refugio County, *E. J. Palmer*, March 22, 1916 (no. 9250, with broadly ovate coarsely serrate leaves and pubescent branchlets); Austin, Travis County, *G. W. Letterman*, August 23, 1892; Dallas, Dallas County, *J. Reverchon*, August 1860 (no. 854), *B. F. Bush*, September 30 and October 27, 1900 (nos. 1190, 1614, 1615), April 8, 1904 (no. 4254); rocky bluffs, Dallas County, *J. Reverchon*, April 15, 1902; bottom lands Elmo, Kaufman County, *J. Reverchon*, October 22, 1902 (no. 3263); "sandy woods, Forks of the Trinity," Dallas County, *J. Reverchon*, (no. 3268); along the Brazos, Bryan, Brazos County, *E. J. Palmer*, April 26, 1918 (no. 13459); Velasco, Brazoria County, *E. J. Palmer*, March 21, 1918 (no. 13133); Columbia, Brazoria County, *E. J. Palmer*, September 29, 1914 (no. 66760); San Augustine, San Augustine County, *E. J. Palmer*, April 1, 1918 (no. 13245); Houston, Harris County, *E. J. Palmer*, March 19, 1918 (no. 13113); *E. N. Plank*, Eagle, Shelby County.

OKLAHOMA.—Sand hills, Ingersoll, Alfalfa County, *C. S. Sargent*, May 6, 1902; near Page, Leflore County, *G. W. Stevens*, September 1913 (no. 2724); low woods along river, Clinton, Custer County, *E. J. Palmer*, July 16, 1917 (no. 1255).

NEW MEXICO.—*A. Fendler*, without locality, 1847 (no. 775 in Herb. Gray); Berendo Creek, Sierra County, *C. B. Metcalf*, May 23, 1904 (no. 926); bank of creek near Roswell, Chaves County, *A. Rehder*, August 16, 1916 (no. 352).

KANSAS.—Woods, Barber County, *A. S. Hitchcock*, 1896 (no. 815 in Herb. Gray); vicinity of Huntsville, Walker County, *R. A. Dixon*, July 1909 (no. 387 in Herb. Gray).

MISSOURI.—Willard, Greene County, *J. W. Blankinship*, August 2, 1893; Noel, McDonald County, *B. F. Bush*, August 7, October 12, 1908 (nos. 4977, 5255), *E. J. Palmer*, September 5, 1913, May 5, 1914, October 11, 1918, (nos. 4141, 5795, 14665, 14668); "along rocky banks," Carthage, Jasper County, *E. J. Palmer*, 1917, Webb City, *E. J. Palmer*, September 28, 1908; Knight's Station, *C. S. Sargent* and *E. J. Palmer*, October 8, 1911 (no. 3489), July 13, 1913 (no. 4019).

MEXICO.—Reynosa, Tamaulipas, on the lower Rio Grande, *C. G. Pringle*, August 7, 1888 (no. 2082); Saltillo, Coahuila, *Ed. Palmer*, 1898.

CELTIS LAEVIGATA TEXANA f. **microphylla,** n. f.—Differing from the variety in its smaller leaves with more prominent reticulate veinlets, and more densely villose-pubescent petioles. Leaves broadly ovate, acute, unsymmetrically rounded at base, smooth, dark green and granulate above, yellow-green below, with villose pubescent midribs and veins and conspicuous reticulate veinlets, 2–2.5 cm. long and 1.5–2 cm. wide. Flowers and fully grown fruit not seen.

A shrub with slender, red-brown branchlets densely pubescent in their first season, becoming puberulous in their second year.

Rocky banks of streams, Sweet Water, Nolan County, Texas, *E. J. Palmer*, May 27, 1918 (no. 13751 type).

CELTIS LAEVIGATA var. **brachyphylla,** n. var.—Differing from the type in the shorter thicker leaves. Leaves ovate, acuminate and long-pointed at apex, very oblique and rounded or cordate at base, entire, occasionally furnished on one side near the base with a broad rounded lobe, glabrous, thick and firm, green on the two surfaces, 3.5–4 cm. long and 2–3 cm. wide, with slender midribs and veins; petioles slender, glabrous, 5–6 mm. in length. Fruit subglobose to short-oblong, bright orange-red, 6–7 mm. in diameter; pedicels glabrous, longer than the petioles.

A tree about 10 m. tall, with slender, glabrous, dark red-brown branchlets.

Rocky banks of the canyon of the Nueces River near Uvalde, Uvalde County, Texas, *E. J. Palmer*, September 26, 1918 (no. 14517 type).

CELTIS LAEVIGATA var. **anomala,** n. var.—Differing from the type in its oblong-ovate, acute leaves, cordate or unsymmetrically

cordate at base, and dark purplish fruit covered with a glaucous bloom. Leaves entire, glabrous, dark green and scabrate above, paler and conspicuously reticulate venulose below, 2–4 cm. long and 1.5–2 cm. wide; petioles sparingly villose pubescent, 4–6 mm. in length. Fruit short-oblong, 6–7 mm. in length, the pedicels as long as or slightly longer than the petioles.

A shrub from 1.5–2 cm. tall with slender pubescent branchlets.

"In deep sands, among shin oak and *Quercus marylandica*," Clyde, Callahan County, Texas, *E. J. Palmer*, September 30, 1918 (no. 14550, type).

CELTIS LAEVIGATA var. **brevipes,** n. var.—*C. brevipes* S. Watson, Proc. Am. Acad. **14**:297. 1879.—Differing from the type in its yellow fruit on shorter puberulous pedicels and in its puberulous petioles. Leaves ovate, acuminate, unsymmetrically rounded or cuneate at base, entire or rarely furnished with occasional teeth, glabrous, dark green and smooth or slightly roughened on the upper surface, yellow-green below with small clusters of pale hairs in the axils of the slender veins, inconspicuously reticulate venulose, 3.5–5 cm. long and 1–2.5 cm. wide; petioles slender, puberulous, 5–7 mm. in length. Flowers not seen. Fruit short-oblong, canary yellow, 5–6 mm. long; pedicels puberulous, shorter or slightly longer than the petioles.

A small tree with slender, glabrous, red-brown branchlets.

ARIZONA.—Camp Grant, Pinal County, *T. J. Rothrock*, July 1874 (no. 337, type of *C. brevipes* in Herb. Gray), *J. G. Lemmon*, 1880 (no. 68 in Herb. Gray)—; along irrigating ditches, Tucson, Pima County, *Engelmann* and *Sargent*, September 24, 1880; banks of Rillito Creek near Tucson, *A. Rehder*, August 7, 1917 (no. 240 type); Apache Trail, Fish Creek, *Alice Eastwood*, April 19, 1917 (no. 6250); Crow Creek Canyon, Chiricahua Mountains, Cochise County, *J. W. Toumey*, July 1894 ("tree 18°×20′–30′"); Tonto Basin, Gila County, *J. W. Toumey*, June 19, 1892.

UTAH.—River Canyon, southeast Utah, *Alice Eastwood*, June 1892.

CALIFORNIA.—Laguna, San Diego County, *D. Cleveland*, July 10, 1885.

The specimens of *C. brevipes* in Herb. Gray and the specimen from San Diego County, California, have only partly grown fruit, but in the shape of the leaves they so closely resemble the yellow-fruited Arizona trees that there can be little doubt that they are of the same variety, although on the Californian specimen the leaves are distinctly rough on the upper surface, as they are in the specimen collected by *Engelmann* and *Sargent* at Tucson.

CELTIS PUMILA Pursh, Fl. Am. Sept. 1:200. 1814; E. J. Hill, Bull. Torr. Bot. Club 27:497. *pl. 33.* 1900.—*C. occidentalis* B *pumila* Muhlenberg, Cat. 100 (*nomen nudum*). 1813; Gray, Man. ed. 2. 397. 1856.—*C. mississippiensis* var. *pumila* Mackensen and Bush, Man. Fl. Jackson County, Missouri, 72. 1902.—Often considered a variety of *C. occidentalis*, *C. pumila* can be separated from that species by its smaller, usually entire, rather thicker leaves, by its small, dark reddish purple fruits on pedicels shorter or only slightly longer than the petioles, by its more deeply pitted nutlet, and shrubby habit. The color of the fruit and its short pedicels indicate a nearer relationship with *C. laevigata* than with *C. occidentalis*.

C. pumila has been found in Pennsylvania, Delaware, and the District of Columbia, western New York, northern Indiana and Illinois, middle Tennessee, northeastern Mississippi, near Augusta, Georgia, near Lake Okeechobee, Florida (*Ed. Palmer*, 1874, no. 515 in Herb. Gray), Missouri, and northeastern Arkansas (Eureka Springs, Carroll County, *E. J. Palmer*, no. 4409).

A branch without fruit, with small, nearly entire, glabrous leaves, collected by *Mohr* on uplands west of Franklin, Alabama, October 8 (no year, no. 66), and described as "a low spreading tree of slender growth," appears in spite of its habit to be *C. pumila*. A glabrous specimen with pedicels as long as or longer than the petioles collected on the sandy seashore at Hillsboro, Florida, by *F. A. Marten* (no. 6506 in Herb. Gray) is probably from a depauperate form of *C. laevigata*.

CELTIS PUMILA var. **georgiana,** n. var.—*C. occidentalis* Abbot and Smith, Insects of Georgia, *pl. 36* (not L.). 1797.—*C. occidentalis* var. *pumila* Chapman, Fl. 417 (not Muhlenberg). 1865.—*C. georgiana* Small, Bull. Torr. Bot. Club. 24:439. 1897; Britton and Shafer, N. Am. Trees, 357, *fig. 316.* 1908.—Differing from the type in the rugose upper surface of the leaves, more or less densely pilose along the midribs and veins below, in the pilose petioles, and puberulous pedicels.

A shrub or small tree occasionally 10 m. tall, with slender pubescent branchlets sometimes becoming glabrous by the end of their first season. The fruit was described as "tan" color by SMALL, and by BRITTON and SHAFER as "red-purple to yellowish." The fruit when fully grown in early summer is dull yellow in color, but by the middle of October it becomes reddish purple like that of *C. pumila*, and is often covered with a glaucous bloom.

C. pumila var. *georgiana* occurs on rocky bluffs, Franklin Furnace, Sussex County, New Jersey (*K. K. MacKenzie*, August 22, 1909, no. 4331), and ranges from the Piedmont region of North Carolina (Raleigh, Wake County, *T. G. Harbison*, June 11, 1918) to western Florida, Autauga and Dallas counties, Alabama, and occurs in southern Missouri (rocky hills and bluffs, *B. F. Bush*, Swan, Taney County, September 23, 1905 [no. 5040], Monteer, Shannon County, August 18, 1901 [no. 703], Noel, McDonald County, August 9, 1908 [no. 5040]). The oldest specimen of this plant which I have seen was collected near Augusta, Georgia, by *Olney* and *Metcalf* in 1855 (in Herb. Gray).

On the rocky wooded slopes and ridges of Lawrence, Orange, Washington, Crawford, Perry, Floyd, and Harrison counties in the extreme southern part of Indiana a dwarf *Celtis* occurs in a few isolated stations. In the general outline of the leaf it resembles *C. pumila*, but the pedicels of the lighter-colored fruits are much longer; the leaves, which are smooth or nearly so on the upper surface and rather thicker than those of *C. pumila*, are slightly pubescent along the under side of the midribs and veins and on the petioles; the branchlets are usually puberulous. Judged by the present inadequate information now accessible concerning this plant it appears intermediate between *C. pumila* and its variety *georgiana*, although the nutlets are smoother than those of *C. pumila*, and it may be distinguished as

CELTIS PUMILA var. **Deamii,** n. var.—Leaves broadly ovate to oblong-ovate, acuminate and often long-pointed at apex, unsymmetrically rounded at base, entire or occasionally sharply and irregularly serrate above the middle, thick, dark green on both surfaces, smooth or slightly roughened above, 3-nerved, reticulate venulose, slightly villose pubescent on the prominent midribs and veins, 6–8 cm. long and 3.5–4 cm. wide; petioles slender, villose pubescent, 8–10 mm. in length; leaves on vigorous shoots acute or acuminate, obliquely rounded at base, thicker, entire, scabrate above, often 10 cm. in length. Flowers not seen. Fruit subglobose, ellipsoidal or slightly obovoid, tan color or orange until after midsummer, becoming when fully ripe dark orange-red, 7–8 mm. in diameter; pedicels 6–15 mm. long.

An arborescent shrub 2–4 m. high, with a stem 3.5–5 cm. in diameter, covered with dark, rough, deeply fissured bark and slender, reddish brown, slightly pubescent branchlets.

C. C. Deam, 6 miles from Derby, Perry County, July 4, 1912 (no. 11502), near Mitchell, Lawrence County, August 16, 1912, September 2, 1915, August 13, 1918 (nos. 12052, 12055, 18474, 18479, 26218), wooded bluffs of the Ohio River west of Leavenworth, September 11, 1915 (nos. 18586, 18589), on a bluff 3 miles south of New Middletown, Harrison County, September 6, 1915 (no. 18727 type), near Big Springs, Washington County, September 12, 1915 (no. 8987), wooded bluff, Indian Creek, near Corydon, Harrison County, August 15, 1918 (no. 26232), near Elizabeth, Harrison County, September 26, 1918 (no. 26798).

I take much pleasure in associating with this plant the name of CHARLES CLEMON DEAM, State Forester of Indiana, who for many years has industriously studied the trees of Indiana.

PERSEA PUBESCENS (Pursh) Sargent.—The first varietal name *pubescens* of PURSH (1814) was taken up for this tree in *The Silva of North America* (7:7. 1895); but under the rules adopted by the Vienna Congress the first specific name must be used, and this is *palustris* (*Tamala palustris* Rafinesque, Fl. Tellur. 137. 1838), and *Persea pubescens* (Pursh) Sargent should become *P. palustris* (Rafinesque) Sargent.

PLATANUS OCCIDENTALIS L.—The leaves of the northern plane tree are broadly ovate, 3–5-lobed by broad shallow sinuses rounded in the bottom, cordate or truncate at base, becoming glabrous except on the under side of the midrib and principal veins, the lobes broad, acuminate, serrate-toothed with long straight or curved remote acuminate teeth. Individual trees with leaves cuneate at base may be distinguished as

PLATANUS OCCIDENTALIS f. **attenuata,** n. f.—Differing from the type in the long cuneate base of the usually less deeply lobed leaves.

I have seen specimens of this form from Selma, Dallas County, Alabama, *T. G. Harbison*, June 31, 1916 (no. 51 type). Mississippi: *T. G. Harbison*, Pelahatchee, Rankin County, May 26, 1915 (no. 14), Jackson and Bolton, Hinds County, June 28, 29, 1916. Texas: *E. J. Palmer*, banks of Peyton's Creek, Matagorda County, May 6, 1916 (no. 9683), rocky creek banks, Boerne, Kendall County, May 19, 1916, Lacey's Ranch, Kerr County, May 31, 1916 (no. 9982). Oklahoma: *G. W. Stevens*, valley of the Chikaskia River near Tonkawa, Kay County. Missouri: *B. F. Bush*, near Monteer, Shannon County, September 1, 1911 (no. 663). Indiana: *C. C. Deam*, low banks of the Wabash River, near Murray, Wells County, May 26, 1916 (no. 19817).

PLATANUS OCCIDENTALIS var. **glabrata,** n. var.—*P. racemosa* Hemsley, Bot. Biol. Am. Cent. **3**:162 (not Nuttall). 1882.—*P. glabrata* Fernald, Proc. Am. Acad. **36**:493. 1901.—*P. densicoma* Dode, Bull. Soc. Dendr. France **7**:67. 1908.—Differing from the type in the 3-lobed leaves, truncate, broad-cuneate or rarely slightly cordate at base. Leaves usually broader than long, truncate, broad-cuneate or rarely cordate at base, 3-lobed by sinuses acute or rounded in the bottom, the lobes long-acuminate, entire, the lateral often furnished near the base with one or rarely with two small acuminate incurved secondary lobes, occasionally found also on the terminal lobe; when they unfold hoary tomentose below and pubescent above; pubescent when the flowers open toward the end of March, and in early summer pubescent along the under side of the midribs and veins but otherwise glabrous, usually 7–14 cm. long and 8–9 cm. wide, their petioles pubescent, becoming glabrous; peduncles with one or occasionally two heads of flowers and fruit.

Described from specimens collected in the Provinces of Coahuila and Nuovo Leon, Mexico, this *Platanus* has been found not to be uncommon in western Texas, where it has been collected by *S. B. Buckley* near Austin (without date or number), by *A. A. Heller*, Kerrville, Kerr County, April 1894 (no. 1622), and by *E. J. Palmer* on the banks of the Llano River at Llano, Llano County, June 23, 1916 (no. 10279), rocky banks of upper Seco Creek, Bandera County, May 18, 1916 (no. 10241), gravel bank, Nueces River, Uvalde, Uvalde County, September 24, 1918 (no. 14480), Fredericksburg Junction and Boerne, Kendall County, June 5 and May 19, 1916 (nos. 9817, 9826, 10069), rocky banks of the Guadalupe River, Kerrville, Kerr County, May 29, 1916 (no. 9921), rocky banks of upper Seco Creek, June 18, 1916 (no. 10241), Utopia and Sabinal, Uvalde County, April 10, 1917, June 7, 1916 (nos. 10100, 11523), rocky banks, Devil's River, Valverde County, October 18, 1916, March 26, 1917 (nos. 11084, 11371), Palliam, Zavalla County, March 21, 1917 (no. 11332).

The close connection of this variety with typical *P. occidentalis* is shown by the appearance on leading shoots of 5-lobed leaves with serrate lobes (*Palmer*, Sabinal, Uvalde County, no. 10100, and Devil's River, Valverde County, no. 110841). More significant perhaps is the fact that occasionally trees occur growing with *P. occidentalis* north of Texas which cannot be distinguished from the Mexican types of *P. glabrata*. Such specimens are those of *E. J. Palmer*, Choctaw County, Oklahoma, July 13, 1916 (no. 10463), the type of *P. densicoma* collected in the Maquoketa River, Jackson County,

eastern Iowa, preserved in Herb. Mus. Paris (photograph Herb. Arnold Arboretum), Biltmore, North Carolina (Herb. Bilt. no. 1271b), and of *John Robinson*, Brookline, Massachusetts, June 1880.

MAGNOLIA VIRGINIANA L.—*M. glauca* L.—This species was based on the *Tulipifera virginiana* Plukenet, Alm. Bot. 379. *pl. 68*, and the *Magnolia foliis ovato-lanceolatis* Linnaeus, Hort. Cliff. 222; Gronovius, Fl. Virg. 61; and the *Magnolia Lauri folia subtus albicante* Catesby, Nat. Hist. Car. 1:39. *pl. 30*.

There are two distinct forms of this tree, one with glabrous branchlets and pedicels and usually narrow leaves, and one with branchlets and pedicels thickly clothed with long, silvery white hairs and often broader leaves. Specimens preserved in the British Museum show that the former is the type of LINNAEUS' species. *Tulipifera virginiana*, etc., of PLUKENET is represented in the Sloan Herbarium by 2 specimens, one in PLUKENET'S own herbarium, the other one of a number of plants collected in Maryland by *Dr. Krieg* and a *Mr. Vernon*. The latter, Dr. RENDLE tells me, agrees with PLUKENET'S figure and has a glabrous pedicel. Of the *Hort. Cliff.* specimens Dr. RENDLE writes: "We have a specimen labeled *glauca*. The species' names, however, in *Hort. Cliff.* are rarely in LINNAEUS' handwriting and *glauca* is in the usual hand, but there is also written in what may be LINNAEUS' own hand *Magnolia* Catesby, with a reference to t. 39; this suggests that LINNAEUS regarded the *Hort. Cliff.* plant as identical with CATESBY'S. The specimen is in flower and has a glabrous pedicel." CATESBY'S specimen in the British Museum has no flower, but his plate plainly shows that the pedicel is glabrous.

The typical *Magnolia glauca* is a small tree rarely more than 10 m. high, or often a shrub. It is the only form which grows from Massachusetts to southeastern Virginia. Farther south it is rare and I have only seen specimens from Newbern, North Carolina, Darlington, Andrews, Bluffton, Georgetown, and Yemassee, South Carolina, and Meldrin, Georgia. Specimens collected in Florida in the vicinity of Eustis Lake, Lake County, by *G. V. Nash* (no. 575) and in the neighborhood of Orlando, Orange County, by *C. H. Baker* and *T. G. Harbison* have petioles, pedicels, and branchlets puberulous. For the form with the pubescent pedicels and branchlets I suggest the name

MAGNOLIA VIRGINIANA var. **australis,** n. var.—Differing from the type in the silky white pubescence on the pedicels and branchlets.

Leaves remaining on the branches until spring without change of color, elliptic to oval, oblong-obovate or rarely lanceolate, with puberulous, pubescent, or tomentose petioles and varying in width from 2.5 to 9.5 cm., trees with the broadest leaves being confined to western Louisiana and eastern Texas. This southern variety of *M. virginiana* is a tree often 20–30 m. high with a tall trunk occasionally 1 m. in diameter, covered with pale smooth bark and short small branches forming a narrow round-topped head, and branchlets more or less thickly covered during their first season with white silky pubescence, usually gradually disappearing in their second year; in southern Florida often much smaller, and on the Everglade Keys, where it is "very common, a shrubby tree up to 3 m. high" (*E. A. Bessey*).

Swamps in the neighborhood of Wilmington, North Carolina, is the most northern station from which I have seen specimens of this tree; it is common in the coast region of South Carolina and Georgia and in all parts of Florida, and the only form of *M. virginiana* in the other Gulf states, where it occurs as far west as the valley of the Nueces River in Texas (San Augustine County), but is much less common west of the Mississippi River than it is farther east. Although it crosses the Florida peninsula this *Magnolia* is most abundant in the coast region. It ranges inland, however, to Cuthbert, Randolph County, in western Georgia, to Tuskegee and Selma, Alabama, and to Tishomingo County in the extreme northeastern corner of Mississippi, and to Winn and Natchitoches parishes in western Louisiana.

MAGNOLIA ACUMINATA var. **ludoviciana,** n. var.—Differing from the type in its broadly obovate, oval, or ovate leaves abruptly short-pointed at apex and rounded or cuneate at base, and in its much larger flowers. Leaves hoary tomentose below and slightly pubescent above when they unfold, becoming when the flowers open glabrous and yellow-green on the upper surface and pubescent on the lower surface with short pale hairs, 15–18 cm. long and 9–13 cm. wide; petioles puberulous, 2.5–4 cm. in length. Flowers 8–10 cm. long, the outer petals up to 4 cm. in width.

A large tree.

Rich woods, West Feliciana Parish, Louisiana, Dessert Plantation near Catalpa, *Cocks* and *Sargent*, April 12, 1916 (type); West Plantation near Catalpa, *Cocks* and *Sargent*, April 10, 1914; near St. Francisville, *R. S. Cocks*, May 15, 1915, and Catalpa, October 15, 1915.

ACER SACCHARUM Marsh.—The lower surface of the leaves of the northern sugar maple is usually green and glabrous, but it is sometimes glaucous or glaucescent and southward is slightly pubescent along the under side of the midribs and veins; and as the pale color of the lower surface of the leaves gives the trees a distinct appearance the varietal name adopted for them by some European dendrologists will probably be helpful. This form becomes

ACER SACCHARUM var. **glaucum,** nov. comb.—*A. saccharinum* var. *glaucum* Pax, Engler Bot. Jahrb. **7**:242. 1886; Wesmael in Bull. Soc. Bot. Belg. **29**:61. 1890.—*A. palmifolium* var. *glaucum* Schwerin, Gartenflora **42**:455. 1893.—The leaves of this variety resemble those of the green-leaved variety in size and shape and are glabrous or in the southern states usually slightly pubescent on the under side of the midribs and veins.

From the North, where it is much less common than the green-leaved form, I have seen specimens of this variety only from Isle-aux-Couvres in the St. Lawrence River, from Prince Edward Island, Nova Scotia, Lake St. John and St. Anne's, Quebec, northern Vermont, Cooperstown, New York, western Pennsylvania, and Youngstown, Ohio; it is more common in southern Michigan and Indiana, and occurs in northeastern Iowa and central Tennessee. It is still more common in Missouri and northern Arkansas, and is the only form I have seen from South Carolina, Alabama, Mississippi, Louisiana, and southern Arkansas, where the sugar maple is not a common tree.

ACER SACCHARUM var. RUGELII Rehder, Cyclopedia Am. Hort. **1**:13. 1900; Sargent, Man. *fig. 515*. 1905.—*A. Rugelii* Pax, Engler Bot. Jahrb. **7**:243. 1886.—*A. saccharinum* subspec. *Rugelii* Wesmael, Bull. Soc. Bot. Belg. **29**:61. 1890.—In *The Silva of North America* this form of the sugar maple was confused, at least in part, with *A. nigrum*. As it is now understood, the leaves of this variety are usually broader than long and are cordate or rounded at base, 3-lobed with long acuminate lobes, usually entire or the lower lobes occasionally furnished near the base with a small rounded lobe; the leaves are 3-nerved, thick, dark green above, green or glaucescent and glabrous on the lower surface, but on specimens collected by *Palmer* at Williamsville, Wayne County, Missouri (no. 6096), and from a large tree with short-lobed leaves at Campbell, Dunklin County, Missouri (*C. S. Sargent*, October 5, 1910), the lower surface of the leaves is thickly covered with loose pubescence.

This variety appears to be rare and local and to occupy a comparatively restricted area. The type station is at Dandridge on the Tennessee River, Jefferson County, Tennessee, and I have seen specimens from Knoxville, Tennessee, Eureka Springs, northwestern Arkansas, Williamsville, Campbell, and Allenton, Missouri, Lansing, Ingram County, Michigan, from Parry Sound, Georgian Bay (*B. E. Fernow*, 1908, a single tree), and Point Pelee in Lake Erie, Essex County, Ontario (*C. K. Dodge*, 1911).

ACER SACCHARUM var. **sinuosum,** n. var.—*A. sinuosum* Rehder, Sargent, Trees and Shrubs, **2**:255. *pl. 195.* 1913.—The distinctive character of *A. sinuosum* was found in a projection into the broad sinus at the base of the leaves formed by the nerves of the 2 upper lobes which form the base of the sinus. Since the species was described, large collections of this maple of the Edwards Plateau in western Texas show that this projection of the nerves is not a constant character and that *A. sinuosum* must be considered a small-leaved form of *A. saccharum.*

This little Texan tree is known only on the banks and bluffs of Cibelo Creek, near Boerne, Kendall County, on the rocky banks of the upper Seco Creek, Bandera County, and at the base of a high limestone bluff near Utopia, Uvalde County. Its isolation is remarkable and interesting, for none of the group of sugar maples grow nearer to the Edwards Plateau than *A. grandidentatum* Nuttall on the mountains in the extreme western part of Texas, *A. floridanum* Pax at Marshall, Harrison County, Texas, and *A. leucoderme* Small and *A. saccharum* var. *glaucum* Sargent in the Red River Valley in southern Arkansas.

ACER FLORIDANUM Pax.—*A. saccharinum* Elliott, Sk. **1**:450 (at least in part). 1821.

The range of this species can be extended northward from River Junction, Florida, which is the type station, through the Piedmont region of Georgia and the Carolinas to the banks of the Roanoke River, near Weldon, Halifax County, North Carolina, and to Dinwiddie County, southeastern Virginia (river banks and low wet woods near McKenney, *W. W. Ashe*). It is common in the neighborhood of Raleigh, Wake County, North Carolina, where it has been largely planted, and is the common and prevailing street tree.

Recent collections show that the variety of *A. floridanum* with villose-tomentose petioles and usually pubescent branchlets is not uncommon. It is the

Var. FILIPES Rehder, Sargent, Trees and Shrubs, **2**:255. 1913.—*A. brachypterum* Wooton and Stanley, Contrib. U.S. Nat. Herb. **16**: part 4, 146. 1913; **19**:411. 1915.

The type station of this variety is Columbus, Muscogee County, Georgia. It has also been collected in Georgia at Cuthbert, near Milledgeville, Mayfield, and on Shell Bluff on the Savannah River below Augusta, at River Junction, Florida, Calhoun Falls, South Carolina, in the streets of Raleigh, North Carolina, at Campbell, southeastern Missouri, and on the San Luis Mountains in southern New Mexico (*A. brachypterum*). This isolated New Mexican station far to the westward of the region usually occupied by *A. floridanum* is remarkable, but in the shape of the leaves, in their pubescence and in that of the petioles, pedicels, and branchlets, and in the length of the wings of the fruit, it appears identical with some of the specimens of the var. *filipes* from the southeastern states.

ACER RUBRUM Linn.—*A. carolinianum* Walter, Fl. Car. 251. 1888.—*A. stenocarpum* Britton in Britton and Shafer, N. Am. Trees 647, *fig. 598*. 1908.—The leaves of the red maple are usually green and glabrous or pubescent below early in the season, generally soon becoming glaucescent or glaucous below and glabrous or they are usually rather longer than broad, generally cordate or sometimes rounded at base, 3–5-lobed by acute sinuses with serrate lobes and slender glabrous petioles; in the autumn they turn scarlet on some trees and bright yellow on others. The flowers are red or yellowish green (var. *pallidiflorum* Pax). The fruit on different trees is red, yellow, or brownish. The branchlets and winter-buds are glabrous.

The red maple grows on the borders of streams, in wet swamps and in upland forests, occasionally on dry hills, and is found from Newfoundland to the banks of the Miami River in the extreme southern part of Florida, and westward to western Wisconsin, Minnesota, eastern Oklahoma, and to the neighborhood of Houston, Harris County, Texas.

A. stenocarpum Britton is based on a single small stunted tree growing on a dry hill of flint rock at Allenton, St. Louis County, Missouri, on which the samaras of the fruit vary in width up to 6 mm. This maple has been growing in the Arboretum for several years.

No other North American tree ranges through so many degrees of latitude as separate Newfoundland from southern Florida. In the shape of the leaves and in their pubescence, and in the size of the fruit, *A. rubrum* shows much variation. The extremes of these varieties have sometimes been considered species, but they are connected by so many intermediate forms that a better idea of the red maple can perhaps be obtained by treating it as a species with the following varieties:

ACER RUBRUM var. TOMENTOSUM Pax, Engler Bot. Jahrb. 7:182. 1886.—*A. Drummondii* Small, Fl. Southern U.S. 741 (insomuch as

relates to Georgia and Florida, not Hooker and Arnott). 1903.—This variety, which was based on trees cultivated in Europe, is distinguished by the close pale pubescence which covers the lower surface of the leaves during the season. The leaves are 5-lobed, cordate or rarely rounded at base, and the petioles are glabrous or slightly pubescent early in the season. The branchlets are usually glabrous and the winter-buds are pubescent.

I have seen specimens of this form of the red maple from Biltmore, North Carolina (Herb. Bilt. no. 116b), from the neighborhood of Augusta, Georgia, from the top of Flagstaff Mountain, Barclay, Alabama, Panther Burn, Sharkey County, Mississippi, Larissa, Cherokee County, Texas (*B. F. Bush*, May 1, 1909, no. 5579), near Page, Leflore County, Oklahoma (*G. W. Stevens*, no. 2617), and swamps near Little Rock, Pulaski County, Arkansas.

A specimen of this variety with pubescent branchlets and winter-buds, and slightly pubescent petioles, collected by *J. K. Small* at the Altamaha River Swamp, Liberty County, Georgia, in June 1895, and specimens collected by *Mohr* in April 1895 at Mount Vernon, Mobile County, Alabama, with broadly ovate, 3–5-lobed, slightly cordate leaves with pubescent petioles, fruit only 3.5 cm. long, and glabrous branchlets, serve to connect the variety *tomentosum* with

ACER RUBRUM var. DRUMMONDII Sarg.—The leaves of this tree are often broader than long, cordate at base, usually 5-lobed, with stouter midribs and veins than those of the other forms of *A. rubrum*. Until nearly fully grown the leaves are covered on the upper surface with scattered pale hairs and are clothed below with thick snow white tomentum which is more or less persistent during the season; the petioles are stouter than those of the other forms of the red maple, and are covered during the season with thick white tomentum similar to that on the under surface of the leaves. This gradually disappears and the petioles often become nearly glabrous in the autumn. The fruit, which ripens in early spring before or with the unfolding leaves, varies from 5 to 6 cm. in length.

This maple, which is a small tree usually not more than 10–12 m. high, inhabits deep river swamps often inundated through the year. It is distributed from the valley of the Hastchatchee River, Forrest County, southern Mississippi, through Louisiana to the valley of the Neches River, Texas (Beaumont and Concord). It is not rare in southern and eastern Arkansas, southeastern Missouri, and occurs in northwestern Mississippi (Morehead,

Sunflower County), and in southwestern Indiana (in a cypress swamp 18 miles west of Decker, Knox County, *C. C. Deam.*)

In the broad 3–5-lobed leaves cordate at base this maple is very distinct from other forms of *A. rubrum*, but trees occasionally occur with 3-lobed leaves rounded at base. This form may be described as

ACER RUBRUM var. DRUMMONDII f. **rotundata,** n. f.—Differing from the variety in the 3-lobed leaves rounded at base.

Specimens of this form have been collected in Louisiana at Chopin, Natchitoches Parish, *E. J. Palmer*, May 6, 1915 (no. 7553 type), and at Glen Gordon, Covington, St. Tammany Parish, *R. S. Cocks*, March 28, 1911; in Texas near Beaumont, Jefferson County, *C. S. Sargent*, April 11, 1915; and in Missouri at Poplar Bluff, Butler County, *G. W. Letterman*, September 3, 1882.

The fruit of this form has not been collected, but the tomentum of the leaves, petioles, and branchlets is that of the var. *Drummondii*. The shape of the leaves shows a transition into

ACER RUBRUM var. TRIDENS Wood.—*A. barbatum* Michaux, Fl. Bor. Am. 1:252 (at least insomuch as related to the leaves). 1803; Elliott, Sk. 1:451 (at least in part). 1821.—*A. carolinianum* Britton in Britton and Shafer, N. Am. Trees 648 (not Walter). 1813.—The leaves of this maple are obovate, narrowed from above the middle to the rounded or rarely cuneate base, 3-lobed at apex, coarsely serrate usually only above the middle, often ovate or oblong-ovate by the suppression of the lateral lobes, green or glaucous and glabrous, pubescent or tomentose on the lower surface. The flowers and fruit are red or yellow.

It has been found from Massachusetts to Florida, Missouri, and in eastern Texas to Harden and Cherokee counties, but is most abundant southward and sometimes, as in Richland Parish, northern Louisiana, it is the prevailing form.

The extreme forms of this variety are distinct, but the 3-lobed leaves often occur on trees with leaves of the normal form of the red maple, and the leaves on vigorous shoots of trees of this variety are often 5-lobed.

WALTER'S specimen of his *A. carolinianum* is preserved in the British Museum and is a typical *A. rubrum*, not the variety *tridens*. The leaves of *A. barbatum* as described by MICHAUX and ELLIOTT seem to be those of *A. rubrum* var. *tridens*. Their "pedunculi solito pilosi" might apply to *A. floridanum filipes* Rehder.

ACER NEGUNDO L.—The box elder or ash-leaved maple, which is one of the most widely distributed trees in the United States, has

assumed slightly different forms in different parts of the country. In what is considered the typical species, which occurs in the region east of the Rocky Mountains, the united part of the samaras of the fruit is more or less constricted at the base into a short stipe, and on the more western forms this constriction usually does not occur. This constriction and its absence, together with the absence or presence of pubescence on the leaves and branchlets, have sometimes been used to separate *A. Negundo* into several species, but the characters on which these species have been based are not particularly important, and it seems better to treat *A. Negundo* as a species with a number of varieties which often intergrade, for the characters on which they are based are not always constant.

In what is considered the typical species the branchlets are green and glabrous; the leaves are usually 3-foliate but occasionally 5–7-foliate; the leaflets are ovate to elliptic or oblong-obovate, acuminate and often long-pointed, rounded or cuneate and often unsymmetrical at base, coarsely and irregularly serrate usually only above the middle, and occasionally slightly lobed, slightly pubescent above and more or less tomentose below when they unfold, and at maturity glabrous above, usually villose-pubescent along the under side of the midribs and veins, and often furnished with conspicuous tufts of axillary hairs, otherwise glabrous or slightly pubescent below.

The typical form is distributed from western New England and central New York to Minnesota, Iowa, and Missouri, and southward to central Florida, northern Alabama, western Louisiana, and eastern Texas. I have not seen specimens of wild trees from eastern New England, eastern New York, New Jersey, or Delaware. The box elder is common along the St. Lawrence River near Montreal and in eastern Ontario, but these trees are believed to have been naturalized in recent years. As here considered it passes into the following varieties:

ACER NEGUNDO var. VIOLACEUM Kirchner in Kirchner and Petzold Arb. Mosc. 190. 1864.—*Rubac Nuttallii* Nieuwland, Am. Middl. Nat. **2**:137. 1911.—*Negundo Nuttallii* Rydberg, Bull. Torr. Bot. Club **40**:55. 1913.—This variety is distinguished by its rather stouter, pale or bluish violet branchlets covered with a glaucous bloom, rather larger buds, and usually 3–7-foliate leaves

with slightly thicker, lanceolate to oblong-ovate or obovate, often entire or irregularly dentate, occasionally lobed leaflets, the terminal leaflet occasionally 3-lobed, glabrous above and usually slightly pubescent over the lower surface; the base of the fruit is usually but not always constricted.

This variety is distributed from western Massachusetts, through New York to Ohio, northern Wisconsin, Minnesota, Iowa, South Dakota, Dufferin, Manitoba, and Nez Perce County, Idaho; it is common in northern Missouri and occurs near Noel, McDonald County, in the extreme southwestern part of that state (*E. J. Palmer*, no. 5479).

ACER NEGUNDO var. TEXANUM Pax, Engler Bot. Jahrb. **7**:212. 1886.—*A. californicum* var. *texanum* Pax, *l.c.* **11**:75. 1890.—*Rubac texana* Small, Fl. Southern U.S. 743 (in part).—*Negundo texanum* Rydberg, Bull. Torr. Bot. Club **40**:56. 1913.—This variety is best distinguished by the 3-foliate leaves with broader ovate to obovate, coarsely serrate leaflets cuneate or rounded at base and covered below through the season with loose pubescence. The branchlets are pale pubescent or tomentose during their first season and the body of the fruit is usually puberulous and slightly or not at all constricted at the base.

This variety occurs in western (Jackson County) and southwestern Missouri, northeastern Kansas, through Arkansas to western Oklahoma and to the valley of the San Antonio River, Texas. It appears to have been collected first by *Lindheimer* near New Braunfels, Texas, in 1843 (no. 360 in Herb. Gray). Eastward it passes into

ACER NEGUNDO var. TEXANUM f. **latifolium,** n. f.—*A. Negundo* var. *latifolium* Pax, Engler Bot. Jahrb. **11**:75. 1890.—Only differing from typical var. *texanum* in its glabrous branchlets and usually glabrous fruit often slightly constricted at the base.

This form occurs in eastern Texas, southern Arkansas, Louisiana, in the valley of the Black River, eastern Mississippi, at Nashville, Tennessee, on the banks of the Catawba River near Marion, North Carolina, in Virginia, and southern Ohio.

ACER NEGUNDO var. **interior,** n. var.—*A. interior* Britton in Britton and Shafer, N. Am. Trees, 655, *fig. 608*. 1908.—?*A. Kingii* Britton, *l.c.* 1908.—*Rulac interior* Nieuwland, Am. Mid. Nat. **2**:139. 1911.—*Negundo interius* Rydberg, Bull. Torr. Bot. Club

40:56. 1913.—*Rulac texana* Small, Fl. Southern U.S. 743 (in part). 1903.—This variety, the box elder of the Rocky Mountains, differs from the variety *texanum* only in its narrower and usually more acuminate and more irregularly serrate, often lobed leaflets usually covered below with a closer pubescence, and in the more pubescent or tomentose petioles and rachis.

It ranges from Manitoba, Saskatchewan, and Alberta southward through Wyoming, Montana, Colorado, Utah, New Mexico, and Arizona. The oldest specimen of this tree which I have seen was collected by *A. Fendler* in New Mexico in 1847 (no. 102 in Herb. Gray).

More distinct is the variety of Arizona and southern New Mexico, which may be described as

ACER NEGUNDO var. **arizonicum,** n. var.—Leaves thin, 3-foliolate; petioles slender, glabrous, 4.5–7 cm. in length, often turning bright red late in summer; leaflets oblong-ovate to rhombic, acuminate and long-pointed at apex, rounded or cuneate at base, coarsely serrate, often slightly lobed near the middle, glabrous at maturity with the exception of conspicuous tufts of axillary hairs, 6–10 cm. long and 3–5 cm. wide; petiolules slender, glabrous, usually bright red, those of the terminal leaflet 2–2.5 cm. in length, the others only 6–7 mm. long. Flowers not seen. Racemes of fruit glabrous, 8–10 cm. in length; body of the fruit spreading, glabrous, not constricted at the base.

A tree 7–8 m. high with light gray fissured bark and slender glabrous branchlets thickly covered with a glaucous bloom.

ARIZONA.—Cave Creek Canyon, east slope Chiricahua Mountains, *J. W. Toumey*, July 1894; Oak Creek Canyon near Flagstaff, Coconino County, *A. Rehder*, July 14, 1914 (no. 34); Sycamore Canyon near Flagstaff, *Percival Lowell*, October 1915 and 1916; Santa Catalina Mountains, *J. G. Lemmon*, May 1881 (no. 128 in Herb. Gray); Mount Kellogg, Santa Catalina Mountains, altitude 2700 m., *A. Rehder*, August 31, 1916 (no. 463 type).

NEW MEXICO.—Kelley's Ranch, 7 miles north of Alma, Socorro County, *A. Rehder*, August 13, 1914 (nos. 279, 280; growing near no. 281, with densely pubescent branchlets and leaflets pubescent below, and so referable to var. *interior*); Glenwood, 7 miles south of Alma, Socorro County, *A. Rehder*, August 14, 1914 (no. 300).

This is the most glabrous of the forms of *A. Negundo*, and in its thin leaflets, bright red petioles, and glabrous branchlets thickly covered with a glaucous bloom one of the most distinct of them all.

ACER NEGUNDO var. CALIFORNICUM Sargent, Garden and Forest, 4:148. 1891; Silva N. Am. 2:112. *pl. 97*. 1891.—*Negundo californicum* Torrey and Gray, Fl. N. Am. 1:250, 684. 1838; Rydberg, Bull. Torr. Bot. Club 40:56. 1913.—*Acer californicum* Dietrich, Syn. 2:1283. 1840; Pax, Engler Bot. Jahrb. 7:213 (in part). 1836; 11:75. 1890.—*Negundo aceroides* Torrey, Pacific R.R. Rep. 4:74 (not Moench). 1857.—*Negundo aceroides* var. *californicum* Sargent, Garden and Forest 2:364. 1889.—*Acer Negundo* subsp. *californicum* Wesmael, Bull. Soc. Bot. Belg. 29:43. 1890.—*Rulac californica* Nieuwland, Am. Mid. Nat. 2:139 (in part). 1911.—Leaves trifoliate with tomentose or nearly glabrous petioles, rachis, and petiolules; leaflets oblong-ovate to rhombic, acuminate and long-pointed at apex, cuneate or unsymmetrically rounded at base, coarsely serrate above the middle or nearly entire, occasionally deeply lobed, glabrous on the upper surface except along the midribs and veins, thickly coated on the lower surface with matted pale hairs and furnished with large axillary tufts. Fruit on pubescent pedicels, puberulous or nearly glabrous, not constricted or rarely slightly constricted at base.

A large tree with dark bark, hoary tomentose branchlets, and winter-buds.

Valley of the lower Sacramento River southward to San Bernardino County, California. The California box elder was discovered by DAVID DOUGLAS in 1833, probably in the neighborhood of Monterey.

FRAXINUS AMERICANA var. **subcoriacea,** n. var.—Differing from the type in its thicker, entire or slightly serrate leaflets, silvery white on the lower surface. Individual trees of *F. americana* occur with thick, oblong-ovate, acuminate, entire or slightly serrate leaflets dark green and lustrous above, silvery white below, glabrous or slightly villose along the midribs, and 7.5–13 cm. long. These trees are so distinct in appearance and in their more rapid and vigorous growth that it seems desirable to give them a varietal designation. What may be considered the type of the variety has been growing in the Arnold Arboretum since 1874, where it was raised from seed sent by *W. C. Hampton* from Mount Victory, Harding County, Ohio, as "*Fraxinus* C." The trees of this variety have grown more rapidly and are handsomer than any of the other American ashes in the collection. In 1910 and 1912 I collected the

same variety at Campbell, Dunklin County, Missouri, where I saw only a single individual. *F. americana* no. 4206, *A.* and *E. G. Heller*, Texarkana, Texas, September 1898, with entire and equally thick leaflets but not so pale below, is probably the same form.

CASTANEA ALNIFOLIA var. **floridana,** n. var.—Differing from the type in the glabrous, lustrous under surface of the mature leaves and in its arborescent habit.

In sandy soil with *Quercus myrtifolia* Willd. on the shores of St. Andrews Bay near Panama City, Bay County, Florida, *T. G. Harbison*, May 28, 1917 (no. 10, type), December 10, 1918 (nos. 13, 14); Dover, Screven County, Georgia, *T. G. Harbison*, May 13, 1913.

A tree occasionally 13–14 m. tall, or sometimes shrubby.

Unfortunately I have not seen the fruit of this tree, but in the shape of the leaves and in their serration, in the inflorescence, and in the glabrous branchlets it is not distinguishable from *C. alnifolia* Nutt. The leaves when they first unfold are hoary tomentose below, and the tomentum is sometimes persistent during the season on the upper leaves of vigorous shoots.

On a specimen of what appears to be the same form collected by *Harbison* near Jacksonville, Florida, the branchlets are slightly puberulous, and there are a few hairs on the under side of the midribs of the otherwise glabrous leaves.

The leaves of a shrub with pilose branchlets collected by *Harbison* on the coast near Wilmington, North Carolina, are broadly obovate and green, lustrous and puberulous on the under surface, and quite different from the leaves of the typical form of *C. alnifolia*, which are narrow-obovate to oblong-elliptic and thickly covered below with pale tomentum.

ARNOLD ARBORETUM
JAMAICA PLAIN, MASS.

POSSIBLE CORRELATIONS CONCERNING POSITION OF SEEDS IN THE POD

BYRON D. HALSTED[1]

This study was made with the Henderson Lima bean on a block of ground one-fortieth of an acre. Nine rows of 10 hills each were planted 5 seeds to the hill in the manner shown in table I.

TABLE I

Row	Position of seeds in pod	Percentage of viability
1	2-seeded base	52
2	2-seeded tip	70
3	3-seeded base	60
4	3-seeded middle	76
5	3-seeded tip	56
6	4-seeded base	64
7	4-seeded first middle	60
8	4-seeded second middle	72
9	4-seeded tip	74
Total		584

Table I shows that seeds from the middle of 3-seeded pods had the highest viability, and that of those from the base of 2-seeded pods nearly one-half failed to produce plants. The average viability of the 3 rows planted with basal seeds was 58.6 per cent, the next lowest 66.6 per cent in the rows planted with tip seeds, and the highest viability 69.3 per cent, obtained in the rows planted with seeds from the middle of 3-seeded and 4-seeded pods.

Table II shows that the pods are chiefly of the 3-ovuled type, and that the others are somewhat equally divided between the 2-ovuled and 4-ovuled pods. The yield of pods from seeds of 2-ovuled pods is 15.61 per cent less than the average yield from seeds of 3-seeded and 4-seeded pods.

Pods from plants grown from seeds borne in the basal position numbered 1463, from seeds from middle position 1735, and in the

[1] This paper was received from the late Professor HALSTED in January 1918. A brief biographical sketch appears in the BOTANICAL GAZETTE of February 1919.

tip position 1403. This is 23.66 per cent more pods from the 3 rows planted with seeds from the middle of the pod than from the same area planted with seeds from the tip position, and

TABLE II

NUMBER AND TYPES OF PODS FOR EACH ROW, BOTH HARVESTS COMBINED

Row	Position of seeds in pod	2-ovuled	3-ovuled	4-ovuled	Total	Average per pod type
1.....	2-seeded base	44	343	17	404	.....
2.....	2-seeded tip	37	449	21	507	455.5
3.....	3-seeded base	55	487	36	578	.....
4.....	3-seeded middle	82	540	34	656	523.0
5.....	3-seeded tip	30	288	17	335	.....
6.....	4-seeded base	44	401	36	481	.....
7.....	4-seeded first middle	16	517	46	579	530.2
8.....	4-seeded second middle	47	388	65	500	.....
9.....	4-seeded tip	60	456	45	561	.....
	Total.....	415	3869	317	4601	.....

18.58 per cent more than the corresponding rows planted with basal seeds.

The percentage of each pod type in the crop for each pod type *planted is given in table III.*

TABLE III

Type planted	2-ovuled	3-ovuled	4-ovuled
2-seeded pods.....	8.88	86.95	4.17
3-seeded pods.....	9.09	84.87	5.54
4-seeded pods.....	9.48	81.11	9.41
Total.....	9.30	83.87	7.33

Table III shows but little variation in the number of 2-ovuled pods, but in 3-ovuled pods there is a decided decrease in the percentage, going from 2-seeded to 4-seeded, and, of course, a corresponding increase in the 4-ovuled pods, and where the percentages are low the differences are great, over 125.66 per cent between the crop from 2-seeded pods and that from 4-seeded pods. In other words, there is seen to be a tendency for seeds from 4-seeded pods to reproduce the mother type of pod. The number of pods for each

harvest and the percentages for the 3 types of pods are indicated in table IV.

TABLE IV

	Number of pods	Percentage of each type of pod		
		2-ovuled	3-ovuled	4-ovuled
First harvest.....	2672	7.11	84.73	8.16
Second harvest.....	1829	11.86	82.87	5.27
Total.....	4501	9.30	83.37	7.33

Table IV shows that the first harvest comprised nearly three-fifths of the total crop. It is further shown that the first harvest has its 2-ovuled pods below the average and its 3-ovuled and 4-ovuled pods above the average, while in the second harvest the reverse is seen. In other words, as the season advanced the average number of seeds in the pods increased.

TABLE V

Number and average weight of seeds

Row	Position of seeds in pod	Pods without aborts		Pods with aborts		Both averaged	
		Number	Average weight	Number	Average weight	Number	Average weight
1.....	2-seeded base	479	0.404 gr.	433	0.434 gr.	456	0.419 gr.
2.....	2-seeded tip	683	0.376	529	0.404	606	0.390
3.....	3-seeded base	881	0.376	539	0.411	710	0.394
4.....	3-seeded middle	912	0.396	662	0.424	787	0.410
5.....	3-seeded tip	413	0.390	371	0.419	392	0.405
6.....	4-seeded base	617	0.392	512	0.420	565	0.406
7.....	4-seeded first middle	799	0.391	630	0.422	715	0.407
8.....	4-seeded second mid.	878	0.385	783	0.415	831	0.400
9.....	4-seeded tip	803	0.360	528	0.387	666	0.378

Table V shows that the largest number of seeds (4624) was taken from the rows planted with seeds from the middle of the pods, while the number of seeds planted from the basal and tip seeds were 3461 and 3377 respectively. The average weight of all seeds from each row approximates the general average, the only striking deviation being in the lightness of the seeds grown from seeds produced in the tip position of 4-seeded pods.

Table VI shows under pod average (seed-weight for the 3 types of pods) that the heaviest seeds are produced in 3-seeded pods and the lightest are found in 4-seeded pods. It is also shown that the seeds in the basal position are lighter than elsewhere in the type of pod considered, and that in the combined harvests the seed weights

TABLE VI

RELATION OF POSITION OF HARVESTED SEEDS IN POD TO WEIGHT: I. SEEDS FROM PODS WITHOUT ABORTS AND AVERAGE FOR ALL 9 ROWS

	2-base	2-tip	3-base	3-middle	3-tip	4-base	4-first	4-second	4-tip	All
Both harvests	0.338	0.366	0.362	0.392	0.412	0.305	0.341	0.341	0.345	0.385
Pod averages	0.352			0.391			0.333			
First harvest	0.314	0.345	0.344	0.375	0.388	0.268	0.319	0.313	0.326	0.360
Pod average	0.329			0.369			0.307			
Second harvest	0.379	0.402	0.399	0.442	0.459	0.361	0.374	0.384	0.375	0.426
Pod average	0.390			0.434			0.374			

make a continuous rising series from the base to the tip for all types of pods. There is an exception in the records for separate harvests, but it is among 4-seeded pods, a type not largely represented, and small deviations are here to be expected. It is noted that the first harvest yields seeds of lighter weight than does the second harvest, and with a single exception (4-seeded base) the difference applies to each position in the pod.

TABLE VII

II. SEEDS FROM PODS WITH ABORTS AND AVERAGE FOR ALL 9 ROWS

	2-base	2-tip	3-base	3-middle	3-tip	4-base	4-first	4-second	4-tip	All
Both harvests	0.404	0.448	0.377	0.403	0.439	0.329	0.361	0.375	0.388	0.414
Pod averages	0.440			0.418			0.373			
First harvest	0.324	0.388	0.344	0.368	0.401	0.271	0.338	0.354	0.374	0.377
Second harvest	0.442	0.473	0.413	0.438	0.476	0.423	0.433	0.403	0.428	0.453

Table VII shows from the pod averages that the weight of the seeds decreases from 2-ovuled pods to 4-ovuled pods, and that the average weight of the seeds in 3-ovuled pods is very close to the average for all seeds. The averages for both harvests show that the lightest seeds are produced in the basal position, and that there is in all types of pods a uniform increase from the weights in the basal position to the weights in the tip position. In the first harvest the seeds in each position in each type of pod are lighter than the seeds for the same position in the second harvest.

A comparison of the weights of seeds for each pod position in the combined harvests of pods without aborts (table III) with those with aborts (table IV) shows that the former are uniformly lighter, as seen in the following statement:

	First harvest	Second harvest	Both harvests
Pods without aborts.....	0.360 gr.	0.426 gr.	0.385 gr.
Pods with aborts.....	0.377	0.453	0.414

The pod averages for seed-weights (tables III, IV) show that the seeds of 3-ovuled pods without aborts are heavier than are the seeds (average weights) in the other two types of pods, while among pods with aborts the average seed weight is greatest in 2-ovuled pods. This is shown in the following figures, in which both harvests are combined:

	2-ovuled	3-ovuled	4-ovuled
Pods without aborts.....	0.352 gr.	0.391 gr.	0.333 gr.
Pods with aborts.....	0.440	0.418	0.373

From these averages it is seen that the differences are considerable, and it may be assumed that it is due to local environment within the pod. For example, in a 2-ovuled pod the average weight of the seeds is 25 per cent more when one ovule aborts, 6.93 per cent in 3-ovuled pods, and 12.01 per cent in 4-ovuled pods. It is noted that the differences are greatest in the extreme or, as they may be called, exceptional pods. The influence upon the remaining seeds when two or more ovules abort in the larger types of pods cannot be determined from the records.

Percentages of gains in weight of seeds associated with aborts over the weight of seeds from pods without aborts for each position in the pod are as follows:

	2-base	2-tip	3-base	3-middle	3-tip	4-base	4-first	4-second	4-tip	All
Pod averages.....	19.25	22.40	4.12	2.81	6.79	7.87	5.87	12.17	12.46	7.79
	20.96		4.57			9.59				

It is seen that the gain of weight of seeds for pods with aborts over corresponding seeds in pods without aborts is greatest in 2-ovuled pods and least in 3-ovuled pods. It is further shown that the weight is most augmented in the tip position in all types of pods, and least in the position next above the base in 3-ovuled and 4-ovuled pods.

TABLE VIII

PERCENTAGE OF ABORTIVENESS FOR EACH POSITION OF SEEDS IN POD

Position of seeds in pod	First harvest	Second harvest	Both
2-seeded base	17.05	26.7	21.81
2-seeded tip	17.30	24.9	21.10
3-seeded base	14.30	23.0	18.65
3-seeded middle	13.10	23.4	18.25
3-seeded tip	17.80	24.8	21.30
4-seeded base	20.0	23.0	21.50
4-seeded first middle	16.2	22.8	19.50
4-seeded second middle	16.0	22.8	19.40
4-seeded tip	17.6	27.1	22.35

Table VIII shows that the abortiveness for each of the 9 rows is less in the first than in the second harvest. When the two harvests are combined, the range is from 18.25 to 22.35 per cent. It is further deduced that the average for the middle seeds (19.05 per cent) is the lowest, while the tip seeds yielded the highest (21.58 per cent) average abortiveness. From the standpoint of percentage of good seeds per pod, the middle seeds are the best for good crop productions.

TABLE IX

PERCENTAGE OF ABORTIVENESS FOR EACH POD POSITION IN WHOLE CROP

	2-base	2-tip	3-base	3-middle	3-tip	4-base	4-first	4-second	4-tip	All
Both harvests	49.55	11.88	40.11	12.95	13.25	52.63	13.93	5.26	4.34	19.75
Pod averages	30.74		.....	19.02	.....	.....	19.04		.....	.....
First harvest	31.77	8.83	47.34	7.96	2.29	55.50	12.84	5.50	3.21	16.83
Pod averages	20.31		.....	15.77	.....	.....	19.26		.....	.....
Second harvest	62.99	14.17	51.28	13.74	4.48	46.66	16.99	4.76	6.66	24.12
Pod averages	38.58		.....	23.17	.....	.....	18.57		.....	.....

Table IX shows that when the two harvests are combined the abortiveness is chiefly in the lower portion of the pod and is very large in the basal position. In all types of pods there is a regular decrease in the number of aborts from the base to the tip, with the

greatest range in 4-ovuled pods. The averages are more nearly alike than averages for position in the pod and are not strictly comparable.

In the first harvest the aborts are nearly two-thirds the number of those in the second harvest, but their distribution among the 9 positions in the pods does not follow fully the rule given for the whole crop. This is shown in the pod averages, where in the first harvest the smallest average is with the 3-ovuled pods, while in the second crop the smallest average is with the 4-ovuled pods.

A greater abortiveness in the second crop may be ascribed to the advanced age of the plants or to the lack of proper insect visitation, but this latter circumstance may not be significant, as Lima beans are understood to be self-fertilized. It is possible, of course, that the cause may be related to the atmospheric conditions prevailing at the time the ovules were ready to set, and this suggests the importance of repeating the present test through a series of years.

TABLE X

AVERAGE WEIGHT OF SEEDS AND PERCENTAGE OF ABORTIVENESS FOR EACH POD POSITION

	2-base	2-tip	3-base	3-middle	3-tip	4-base	4-first	4-second	4-tip	All
Seed weight ..	0.338	0.366	0.362	0.392	0.412	0.303	0.341	0.341	0.345	0.385
Abortiveness.....	49.55	11.85	40.11	12.95	3.25	52.63	13.93	5.26	4.34	19.75
Seed weight ..	7.0	3.0	4.0	2.0	1.0	8.0	6.0	6.0	5.0	.....
Abortiveness.....	2.0	6.0	3.0	5.0	9.0	1.0	4.0	7.0	8.0	.....

The ranking figures make it easier to compare the relationship of the average weights and abortiveness among their respective units. Table X shows at once that the position yielding the heaviest seeds has the lowest percentage of abortiveness, and, contrariwise, the position with the lightest seeds has the largest number of aborts. It is evident that the type of pod has much influence upon the weight of the seed, and it is only proper that the comparison here made should be within the pod. With this consideration in mind it is seen that the order from base to tip with all the pods is reversed, that is, the base bears the lighter (or lightest) seeds and with more (or most) abortiveness.

On account of the influence of pod type upon seed-weight and abortiveness it follows that the relative seed-weight does not necessarily determine the amount of abortiveness. For example, 2-ovuled pods bear seeds at their tips that are of the same weight as those formed at the base of 3-seeded pods, but the relative abortiveness is 11:40.

Summary

1. The greatest viability in Henderson Lima beans is associated with the seeds that are borne in the middle of the pods.

2. Three-seeded pods make up more than four-fifths of the crop; 3-seeded and 4-seeded pods are more numerous in the second of the two field harvests of ripe pods.

3. Seeds from the middle of the pod produce a much larger number of pods than do seeds from the base or tip.

4. The heaviest seeds are produced in 3-seeded pods, and the lightest in 4-seeded pods.

5. The seed weights make a continuous rising series from the base to the tip for all types of pods.

6. The first harvest yields lighter seeds than does the second harvest in each pod position.

7. The seeds associated with aborts are heavier than are those in full pods in each type of pod, and each position in the pod.

8. The abortiveness is less in the first than in the second harvest, and is least in the rows grown from seeds from the middle of the pods.

9. Abortiveness is chiefly in the basal position and decreases regularly from the base to the tip of the pod.

10. The position of the pod that yields the greatest weight of seed is associated with the lowest percentage of abortiveness.

EMBRYO AND SEEDLING OF DIOON SPINULOSUM

SISTER HELEN ANGELA DORETY

(WITH PLATES X, XI)

Dioon spinulosum Dyer, imperfectly and incompletely described by EICHLER[1] in 1883, and by DYER[2] in 1885, but fully and carefully by CHAMBERLAIN[3] in 1909, is, like the other 2 species of *Dioon*, endemic in Mexico. The embryos and seedlings which furnish the material for this study were grown from ovules collected by Dr. CHAMBERLAIN in the mountains about Tierra Blanca and Tuxtepec during his several trips to the *Dioon* country. The tree is described by him as a magnificent ornamental cycad 30–40 ft. high. Unlike *D. edule*, it grows rapidly, and in 2 years makes a handsome greenhouse plant with a crown of large, fernlike leaves.

The unique appearance of the plant and the great size of its ovulate strobilus and ovules led to the expectation of great peculiarities in its vascular anatomy and cotyledonary arrangements. The investigation has verified these expectations only in part. The study of the vascular anatomy of the embryo and seedling of *D. spinulosum* merely serves to emphasize the general harmony which prevails among the cycads in this respect.

Embryo

The seed, like those of all cycads, is filled with a massive endosperm stored with starch. Upon this tissue the proembryo and embryo proper are nourished, apparently without any resting period. When the embryo has attained a length equal to that of the seed itself, pressure is exerted upon the stony coat, and the thin region near the micropyle is broken. Fig. 1 shows a seed with a young embryo borne on the twisted suspensor; fig. 2 represents

[1] EICHLER, A. W., Ein neues *Dioon*. Gartenflora 2:411. 1883.

[2] DYER, SIR W. T. THISTLETON, Biologia Centrali Americana, Botany 3:190. 1885.

[3] CHAMBERLAIN, C. J., *Dioon spinulosum*. BOT. GAZ. 48:401–413. 1909.

a later stage in which the embryo has attained its full length, has broken the seed coat, and pushed out the dried remains of the suspensor and archegonial wall.

The embryo at this stage consists of cotyledons, plumule, and a basal part which in its upper portion is hypocotyl, and in its lower portion root sheath; for the root is endogenous, and is not preceded by any structure which might be looked upon as a "radicle" or "caulicle." The hypocotyl is extremely short, and the distinction between it and the root sheath cannot be determined superficially, but only by study of the internal structure. The number of cotyledons varies from 2 to 4, and all stages of their union are represented (figs. 20–22, 24).

The vascular cylinder of the hypocotyl is a protostele. It has 4 easily recognized protoxylem groups, in no way differing from the hypocotyl cylinders of *Ceratozamia*[4] and *Microcycas*.[5] The cotyledons are multifascicular, like those of *Ceratozamia* and *Microcycas*, and unlike those of *Zamia* and *Dioon edule*. In the embryos which are dicotyledonous, the manner in which the cotyledonary traces are supplied from the hypocotyl cylinder is exactly the same as that described by THIESSEN[6] for *Dioon edule*, and which COULTER and CHAMBERLAIN[7] have shown to be characteristic of the cycads. When the embryo has 4 cotyledons, each cotyledon is on a side of the quadrangular node, and receives a secondary bundle from each of the adjacent angles. Twelve out of 100 embryos had 4 cotyledons, and in each case the vascular strands arose in this manner. In the tricotyledonous embryos (there were 4 of them in 100), one of the 3 cotyledons was supplied in the dicotyledonary manner, and the other two after the manner of the embryos with 4 cotyledons; and yet, at a level just above the tip of the plumule, the number of vascular strands was about equal in the 3 cotyledons. The strands

[4] DORETY, HELEN A., The seedling of *Ceratozamia*. BOT. GAZ. 46:203–220. *pls. 12–16*. 1908.

[5] ———, Vascular anatomy of the seedling of *Microcycas calocoma*. BOT. GAZ. 47:139–147. *pls. 5, 6*. 1909.

[6] THIESSEN, REINHARDT, The vascular anatomy of the seedling of *Dioon edule*. BOT. GAZ. 46:357–380. *pls. 23–29*. 1908.

[7] COULTER, J. M., and CHAMBERLAIN, C. J., Morphology of gymnosperms. Chicago. 1910.

are endarch where they separate from the hypocotyl cylinder (fig. 28); they become mesarch just after they enter the base of the cotyledon (fig. 27) and maintain that character throughout the greater length of the organ; near its tip, however, they are exarch (fig. 26). In all cases the orientation is collateral ectophloic, although at levels where branching is effected there is always an apparent concentric arrangement where the 2 xylem masses are still in contact, and the phloem masses are swung to right and left of them. Transfusion tissue accompanies the metaxylem. Mucilage ducts and tannin cells are abundant.

The root meristem is plainly visible below the hypocotyl plate in embryos of the age shown in fig. 2, but no differentiation has taken place, and of course there is no vascular tissue. The 4 poles of the root are later developed in connection with the 4 protoxylem groups of the hypocotyl vascular plate.

The plumule consists of 3 or 4 abortive scales inclosing the rudiments of the first and second true leaves, sometimes of a third leaf, and the stem tip. There is no means of distinguishing between the stem tip rudiments and those of a new leaf, because the leaf meristem grows much more rapidly, and soon overtops the stem tip (fig. 14). The vascular system supplying all these bracts and leaves is complicated by the well known habit of girdling, the details of which have fascinated and baffled many investigators. Although *D. spinulosum* differs in no way from the other cycads in this respect, its greater size makes a naked eye drawing possible and thus furnishes a means for solution and demonstration. Figs. 14 and 15 were drawn from macerated stems. Each node of the stem is, like the nodes on a first year stem of foxglove, telescoped within the older one instead of growing above it. The internodes are not elongated because the primary meristem of the stem tip is held in check by the more rapidly growing secondary meristem for each developing leaf. Since each leaf is supplied with strands from cauline bundles in different parts of the stem, those strands which come to it from the opposite side of the stem describe almost a semicircle to reach the leaf; those which arise on the same side as the leaf pass directly into it; and small arcs are described by those strands which arise in intermediate positions. In fig. 14

the traces for the older leaf (1^1) are supplied from the cauline strands numbered 2, 7, 14, 17, and 20. The strands from 2 and 20 will girdle the stem cylinder, those from 7 and 17 will make a partial girdle, and that from 14 will enter the leaf petiole directly. Fig. 15 is an attempt at demonstrating the same condition lower down in the stem. For the purpose of making the condition clearer the vertical magnification was made greater than the horizontal one.

Many angiosperms which have both "radical" and cauline leaves give illustration of this same condition. In the second year stems of such plants each node is located at some distance above the older one, and the leaf traces arising on the side of the stem opposite the leaf describe a spiral or oblique arc before entering the leaf. In the part of the stem from which the so-called "radical" leaves spring, however, the vascular strands destined for these leaves describe a horizontal arc similar to the leaf trace girdle in all parts of the cycad stem.

A careful but vain search was made for cortical cambium, vestigial traces of the primitive polystele of the Cycadofilicales.

Germination

Germination is hypogean, like that of all other members of the order thus far described. When the embryo has grown to the full length of the seed, the thin portion of the stony coat surrounding the micropyle yields to the pressure exerted upon it by the base of the axis. This base, scarcely more than a root sheath, emerges, pushing before it the brown and withered remains of the suspensor and archegonial wall. The cotyledonary base elongates and bends downward, and the root tip emerges from its sheath (fig. 3). If the embryo is a monocotyledonous one, that is, if its whole cotyledonary apparatus is a single sheath surrounding the plumule, this sheath is split by the radial growth of the axis; if there are two or more distinct cotyledons, their petioles are separated by the same cause (fig. 4). The plumule then emerges from the seed and becomes erect. Of course, when the seeds germinate while in a vertical position, the root and the plumule develop in the same axis (figs. 5, 6). In 3 of the seeds double embryos developed (fig. 29).

Seedling

The primary root persists indefinitely as a tap root. Large quantities of starch are transferred to it through the cotyledons, and it becomes large and swollen. The small lateral roots arise in whorls, usually of 4, and become a matted mass of fibers. Almost all the greenhouse grown seedlings have their roots hypertrophied, and the root tips have the characteristic tubercles described by LIFE[8] in *Cycas*.

The first leaves are yellowish scales, although thick and fleshy. They bear stipules like those of the foliage leaves, and some of them manifest the typical circinate venation (figs. 10, 11). The true leaves have been described by CHAMBERLAIN in the work previously cited. The first true leaves of several of my seedlings had as few as 6 pairs of leaflets (fig. 9), but most of them had 12 or more. There is great variation in the size of leaves of plants grown in the same conditions and from the same sized seeds. One plant bore small leaves with leaflets 2×0.3 cm., while another just beside it bore on its first leaf 12 pairs of leaflets, each one of them 6×1.1 cm. Imitation of the moist air conditions under which the first leaves of *Ceratozamia* became foliage leaves was unsuccessful with *Dioon spinulosum*.

The stele of the primary root is tetrarch, changing to diarch in its later formed portions and in the lateral branches. The relative size of the vascular cylinder to the whole root in various levels is shown by figs. 16–19. In the hypocotyl the diameter of the vascular cylinder is only about one-seventh that of the whole axis. The manner in which the radial position is achieved in the root is illustrated in figs. 18 and 19.

The leaf traces are always endarch and collateral, and their arrangement in the petiole as shown in cross-section presents the well known omega-shape. Branching and anastomosis are frequent throughout the petiole, but there is in general a diminution of traces toward the top of the leaf.

The plant is a much more rapid grower than *Dioon edule*, and is far more graceful. Under favorable conditions in the greenhouse,

[8] LIFE, A. C., The tuber-like rootlets of *Cycas revoluta*. BOT. GAZ. 31:265–271. 1901.

plants made 3 and 4 leaves, each 1 m. long and 14 cm. wide, in less than a year after emerging from seed.

Summary

1. The cotyledons of *Dioon spinulosum* vary in number from 2 to 4, and they are often lobed and divided so as to appear greater in number. In rare cases the cotyledonary sheath is undivided except near the tip.

2. They are multifascicular, like those of *Ceratozamia* and *Microcycas*, rather than like those of *Zamia* and *Cycas*, which have but few strands.

3. The arrangement and orientation of the vascular strands of cotyledons, hypocotyl, stem, leaves, and root do not differ in any marked degree from the general cycad arrangement.

4. The stem is large enough to demonstrate the cause of the girdling habit and to bring it into alignment with certain angiosperms of the same habit.

5. There is no extrafascicular cambium or any other vestige of polystyle.

Grateful acknowledgment is due to Dr. CHARLES J. CHAMBERLAIN for the generous supply of material from which this study was made.

COLLEGE OF ST. ELIZABETH
CONVENT, NEW JERSEY

EXPLANATION OF PLATES X, XI

The drawings 1–13 and 29 were made with the unaided eye and are reduced to one-half the natural size; 14–19 are diagrammatic; the remainder were made with the aid of the Abbe camera lucida. The following abbreviations have been used: *c*, cotyledon; *l*, leaf; *s*, suspensor; *sc*, scale leaf; *st*, stipule; *vc*, vascular cylinder; *x*, xylem; *ph*, phloem; *px*, protoxylem; *mx*, metaxylem; *ep*, inner epidermis of the cotyledons.

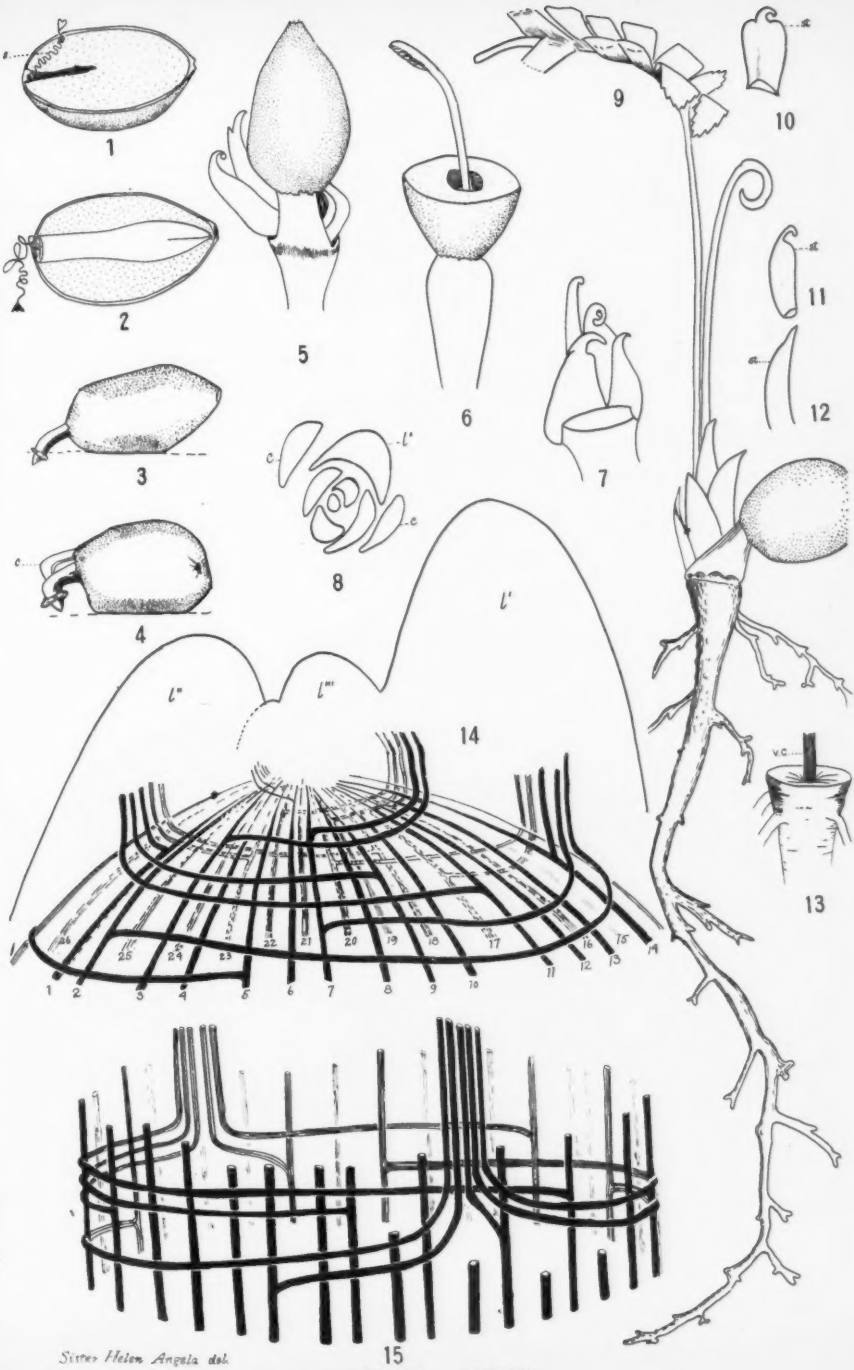
FIG. 1.—Ovule with young embryo and coiled suspensor.

FIG. 2.—Seed with mature embryo, pushing out suspensor and archegonial wall.

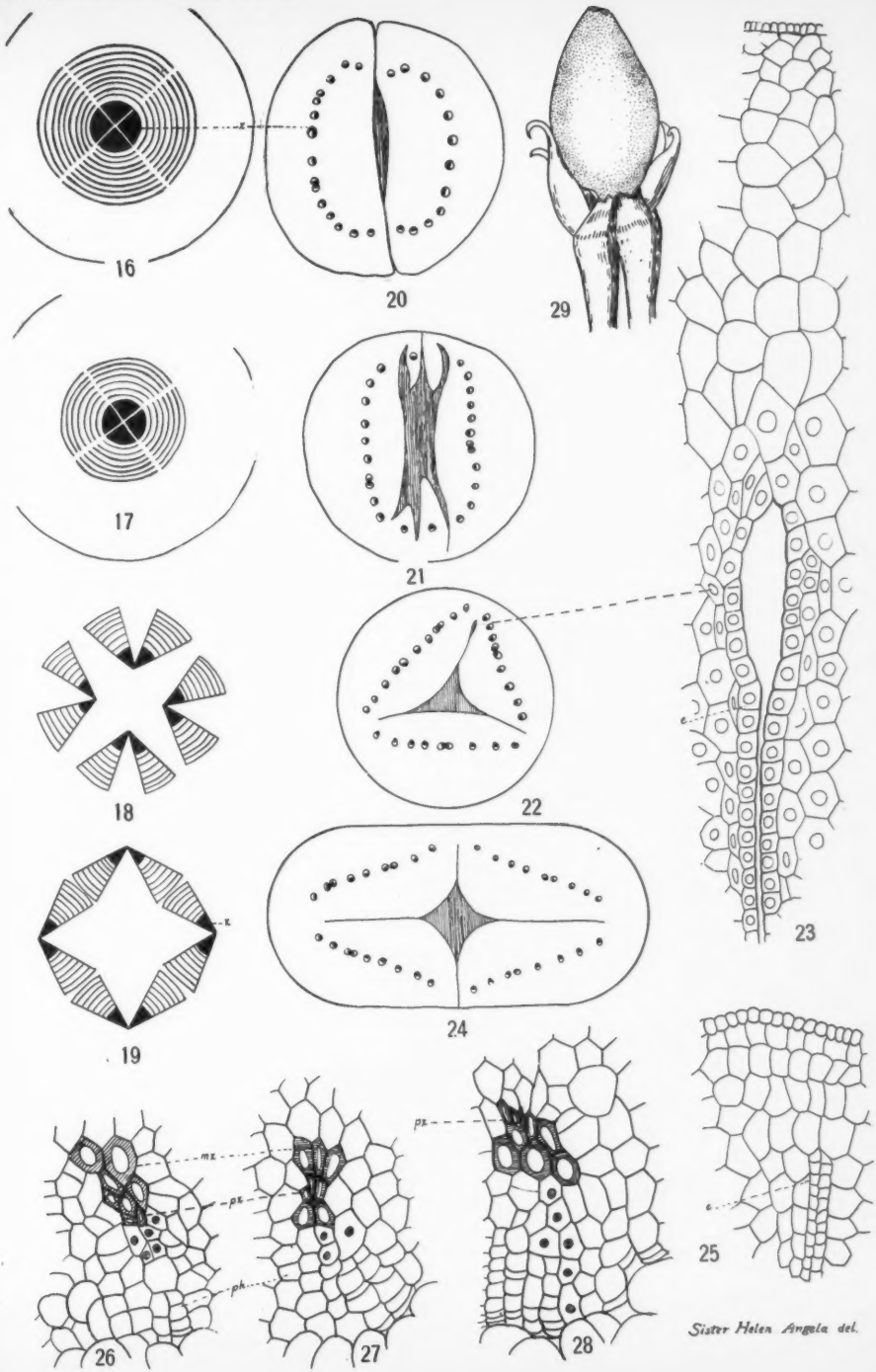
FIG. 3.—Beginning of germination.

FIG. 4.—Separation of cotyledonary petioles.

FIG. 5.—Seedling germinated in vertical position.



DORETY on DIOON



DORETY on DIOON

FIG. 6.—Germination of lower half of seed.

FIG. 7.—First scale leaves, side view.

FIG. 8.—Cross-section of cotyledons and plumule, showing approximately opposite arrangement of leaves.

FIG. 9.—Seedling 2 months after germination.

FIGS. 10–12.—First, second, and third scales respectively.

FIG. 13.—Size of vascular cylinder to relative root.

FIG. 14.—Diagram showing cause of girdling of leaf traces and apparent absence of stem tip.

FIG. 15.—Girdling of leaf traces lower down in stem; vertical magnification greater than horizontal.

FIG. 16.—Diagram of hypocotyl cylinder or "plate."

FIG. 17.—Section 1 mm. below fig. 16.

FIG. 18.—Transition to root arrangement; separation of phloem masses of 4 poles.

FIG. 19.—Vascular cylinder of root.

FIGS. 20–22, 24.—Cotyledonary variations.

FIGS. 23, 25.—Details of arrangement of epidermis over inner sides of cotyledons and cotyledonary sheath.

FIG. 26.—Exarch bundle from tip of cotyledon.

FIG. 27.—Mesarch bundle from central part of cotyledon.

FIG. 28.—Endarch bundle from base of cotyledon.

DEVELOPMENT OF STROPHARIA EPIMYCES

W. B. McDOUGALL

(WITH TEN FIGURES)

Stropharia epimyces (Peck) Atk. was first described by PECK (9) in 1884 as *Panaeolus epimyces*. It was redescribed by ATKINSON (1) in 1902 and again in 1907 (2), and placed in the genus *Stropharia* because of the purplish tinge of the spores and the presence of an annulus. It is considered rare, but it has occurred in several localities north of Urbana during each of the 4 summers I have spent in Illinois, and was particularly abundant during the seasons of 1915 and 1916.

As is well known, this plant always occurs as a parasite on another mushroom. The identification of the host plant was first published by ATKINSON (1) as *Coprinus atramentarius*. Later a second host, *C. comatus*, was added by SHERMAN (10). All specimens collected at Urbana have been on *C. comatus*. Several photographs of *Stropharia epimyces* and its host were published by McDOUGALL (8), and excellent photographs were also published by ATKINSON (2).

Material for the developmental study of this plant was obtained within the city park of Urbana in Spetember 1915. It was imbedded, sectioned, and stained with fuchsin.

Development

The smallest carpophore sectioned measured 0.9 mm. by 1.2 mm. (fig. 1). In this the pileus and stem fundaments cannot be said to be differentiated, but the primordium of the hymenophore already appears as a patch of heavily stained hyphae on each side of the median longitudinal section. Aside from this hymenophore primordium there is no differentiation of the carpophore at this stage, except a layer of coarse and rather loose hyphae on the periphery, representing the universal veil or blematogen. The size of the carpophore is not always an index of its degree of

development, since the carpophore shown in fig. 2 is considerably larger, although little if any further developed than that shown in fig. 1; but in any case the first internal differentiation is the appearance of the hymenophore primordium.

The rapid growth of the elements of the hymenophore as the carpophore enlarges, together with the cessation of growth, or at least very slow growth of the ground tissue below the hymenophore primordium, soon cause the formation of an annular gill cavity (figs. 3, 4). The presence of the annular gill cavity makes it easy to see in longitudinal section which parts of the carpophore

FIG. 1

FIG. 2

FIGS. 1, 2.—*Stropharia epimyces:* fig. 1, small carpophore showing primordium of hymenophore as only differentiation; fig. 2, larger specimen at same stage of development.

in general belong to the pileus fundament and which to the stem fundament, but it is not until still later that these are clearly distinguished.

The gill cavity enlarges rapidly (fig. 5), but it does not become very large before the formation of the lamellae by the downward growth of hyphae from the hymenophore begins (figs. 6, 7). By this time also, if not earlier, the universal veil has disappeared, and the mature carpophore is without any trace of it. ATKINSON (4) has explained in detail the development of the lamellae in

Agaricus Rodmani. The development in our plant is similar and therefore the details need not be repeated here. The same author

FIG. 3

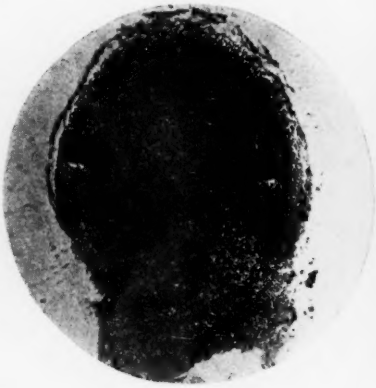


FIG. 4

FIGS. 3, 4.—*Stropharia epimyces:* stages in development of annular gill cavity.

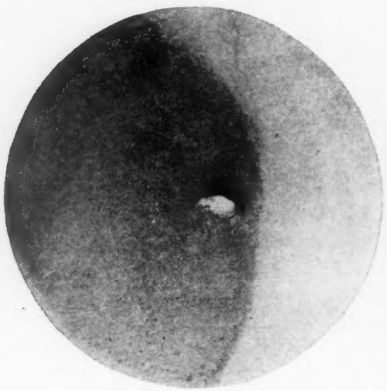


FIG. 5

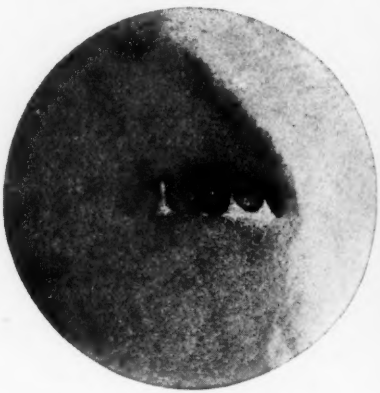


FIG. 6

FIGS. 5, 6.—*Stropharia epimyces:* fig. 5, late stage in development of annular gill cavity; fig. 6, early stage in development of lamellae.

has explained the rather deceptive "stalls" or "pigeon holes" formed by the lamellae at the stem end in longitudinal sections of carpophores in which the lamellae are attached to the stem.

Such "stalls" are shown in figs. 8 and 9, and prove that the lamellae are attached to the stem at this stage of development.

FIG. 7

FIG. 8

FIGS. 7, 8.—*Stropharia epimyces:* fig. 7, late stage in development of lamellae; fig. 8, similar stage cut to show "stalls," indicating that gills are attached to stem.

FIG. 9

FIG. 10

FIGS. 9, 10.—*Stropharia epimyces:* fig. 9, portion of expanding carpophore showing "stalls," indicating that gills are attached to stem; fig. 10, portion of expanding carpophore showing the rather slight inner veil.

The inner veil which develops from the ground tissue below the hymenophore primordium remains intact until the lamellae are

well developed, but it usually ruptures before the stem is much elongated (fig. 10) and forms a rather slight ring on the stem. The subsequent elongation of the stem results in the position of the ring near the stem base.

Discussion

As ATKINSON (5) has said, the few species of Agaricaceae with endogenous origin of the hymenophore, whose development has been studied, fall into 3 groups, based on the order of differentiation of the pileus, stem, and hymenophore fundaments in the carpophore. In the first of these groups the pileus primordium is differentiated first. This group is represented by *Hypholoma sublateritium*, *H. fasciculare*, *Amanita rubescens*, and *Amanitopsis vaginata*. A second group includes those species in which the stem primordium is first differentiated, this being followed by the differentiation of the pileus primordium and later of the hymenophore primordium. This group is represented by *Lepiota cristata*, *L. seminuda*, and *Rozites gongylophora*. In the third group the hymenophore primordium appears while the remainder of the carpophore is seemingly undifferentiated, and the distinction of pileus and stem comes later. In this group we find *Agaricus campestris*, *A. arvensis*, *A. Rodmani*, *Armillaria mellea*, and *Stropharia ambigua*.

Stropharia epimyces, from its mode of development, is to be placed in the third group mentioned. This may be taken as additional evidence, if any further evidence is needed, that our plant belongs to the genus *Stropharia* and not to *Panaeolus*, as was first thought by PECK, since the type of development is the same as that of the only other species of *Stropharia* that has been studied (11) and of species of the closely related genus *Agaricus*.

Stropharia epimyces as it occurs at Urbana agrees in detail with the description given by ATKINSON (1, 2), except that it occurs on *Coprinus comatus* instead of *C. atramentarius* as did those collected by ATKINSON. The recognition of the host plant was easy in this case since there were many uninfected plants growing along with the infected ones, and also many plants which had "pinhead" and "button" stages of the parasite on them but were not deformed to such an extent as to be unrecognizable. The spores are distinctly purple-black in color. The annulus is often not very prom-

inent, but is usually perfectly apparent. The lamellae in mature specimens are adnate to adnexed.

HARPER (**6, 7**) has suggested that *Stropharia epimyces* is identical with *Pilosace algeriensis* (Fries) Quel. While it is entirely possible that this may be true, our plant cannot belong to *Pilosace*, as we understand that genus, since it has an annulus and the lamellae are not free.

The fact that all species of *Agaricus* and *Stropharia* thus far studied (*Agaricus comtulus*, see ATKINSON, **3**, is a possible exception) develop in the same way is of interest as indicating a close relationship between these two genera. The main taxonomic characters that have been used to distinguish these genera are the free gills in *Agaricus* and the attached gills in *Stropharia*. ATKINSON (**4**), however, has found that in developmental stages of *Agaricus Rodmani* the gills are often attached, and that even in mature specimens of *A. Rodmani* and *A. campestris* the gills are sometimes adnexed, thus indicating that such characters do not clearly distinguish the genera.

UNIVERSITY OF ILLINOIS
URBANA, ILL.

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BRIEFER ARTICLES

HYBRID PERENNIAL SUNFLOWERS

From time to time references have been made to supposed hybrids between the perennial sunflowers, but there has been no systematic investigation of the subject. Such hybrids, if formed, might in many cases reproduce vegetatively, and so give rise to an essentially uniform group of plants of considerable extent, having the aspect of a true species.

At Boulder, Colorado, *Helianthus orgyalis* and *H. Maximiliani* have been growing in close proximity for a number of years. There has appeared close to these plants a distinct form which can hardly be anything but a hybrid between the two. Possibly such hybrids will be found growing wild in Nebraska, Missouri, or Texas, if anywhere the ranges of the parent species overlap. In order to bring out the characters of the new plant it is necessary partly to redescribe the supposed parents, especially since the descriptions in the manuals omit several significant characters. The 3 plants involved will be distinguished by the following numbers: (1) *H. orgyalis* DC.; (2) *H. orgyaloides*, nov. (the presumed hybrid); (3) *H. Maximiliani* Schrad.

Stems: (1) very smooth and glaucous to top, much branched, the branches slender; (2) essentially smooth, but roughish to the touch above, nearly as stout as in *Maximiliani*, and with few branches or short peduncles as in *Maximiliani;* (3) stout, little branched, scurfy, with matted white hairs, thinly hairy at top.

Leaves: (1) linear, crowded on stem, 1-nerved, but with a strong marginal nervure; surface glabrous; margins slightly undulate, with mere traces of obsolete teeth; width of stem leaf 6 mm.; (2) linear, appearing as in *orgyalis*, but up to 12 mm. broad, rough to the touch, remotely and indistinctly subdentate; a continuous but looped submarginal nervure; (3) broadened, narrow lanceolate, grayish, more or less scabrous on both sides, margins remotely and feebly dentate; no continuous marginal nervure; width of stem leaf 26 mm.

Peduncles: (1) slender; (2) stoutish; (3) stout.

Disk: (1) dark; (2) yellow, pale green in bud; (3) yellow.

Phyllaries: (1) linear, long, and spreading; (2) long, narrow, and spreading, of the *orgyalis* type; (3) lanceolate, loose, and spreading.

Rays: (1, 2, 3,) without pistils; (1) 11–14, rather more decidedly orange than in *Maximiliani*, and more or less bifid at end; (2) 14–21, clear bright orange-yellow, essentially *Maximiliani* color, many with tips deeply bifid; (3) 30, light yellow, more or less emarginate at end, and largely in 2 rows.

Diameter of disk: (1) about 10 mm.; (2) about 16 mm.; (3) about 17 mm.

Disk bracts: (1) very hairy at end, covering disk buds at early stage; no produced naked tips; (2) very hairy at end, covering disk buds at early stage, and with short naked tips; (3) hairy at end, covering disk buds at early stage, their tips elongate and sharp, pale green, not hairy.

Stigmatic branches: (1, 2, 3) orange.

Achenes: (1, 2, 3) entirely glabrous.

Pappus scales: (1) 2, about or hardly half length of corollas; (2) 2, about as long as in *orgyalis*, sometimes with well defined intermediate squamellae; (3) over half length of corollas.

The hybrid is on the whole intermediate. It is surprising that the dark disk is not dominant. A remarkable feature is the deeply bifid ends of the rays in the hybrid, greatly exaggerating the character of the parents. The appearance of intermediate pappus squamellae is a common feature in true *orgyalis*. Essentially this hybrid is evidently known to the trade, although not described. We have a purchased plant belonging to it, but differing from the one just described in the following particulars: stems freely branching as in *orgyalis*, and plant as tall as *orgyalis*;[1] disk olive green in bud; peduncles rather slender; rays 18–24, only slightly emarginate at end; disk about 15 mm. in diameter; lobes of disk corollas light orange, the extreme tips reddened, or whole lobe suffused with red. F. C. HEINEMANN, of Erfurt, Germany, advertised a supposed hybrid of this group, calling it *H. perennis hybridus pyramidalis;* but from his figure it seems to be simply *H. Maximiliani.*

It is clear that our hybrid does not agree with *H. Dalyi* Britton or *H. Kellermani* Britton. Dr. J. C. ARTHUR writes me that some years ago, near Madison, Wisconsin, he saw a considerable growth of *H. Kellermani*, and near by *H. grosseserratus* and *H. orgyalis*, or what appeared to be such. He had the idea that *H. Kellermani* was a hybrid between the latter plants, but on attempting to make the same cross

[1] C. PURDY (1916) advertises a very tall form of *H. Maximiliani*, said to grow to 11 ft. in height. Is this perhaps a hybrid?

artificially at Lafayette, he was unable to get any seed. *H. Dalyi*, according to FARWELL, is a variety of *H. Maximiliani*, related to it much as var. *oppositifolius* Farwell is related to *H. giganteus*. An effort should be made, however, to raise a *giganteus*×*Maximiliani* hybrid. *H. ambiguus* (Gray) Britton is supposed to be a hybrid *giganteus*× *divaricatus*, or at any rate to have *giganteus* as one parent. THELLUNG records a garden hybrid *laetiflorus*×*rigidus*, and the plant called *H. serotinus* Tausch (1828) is supposed to be *strumosus*×*rigidus*. Evidently there is a great deal to be done, both in the field and in the garden, before we can reach a fairly clear understanding of this subject. It seems possible that in this genus the origin, through hybridization, of distinct plants, with the attributes of species, may be demonstrated.—T. D. A. COCKERELL, *University of Colorado, Boulder, Colo.*

RELATIONSHIPS WITHIN THE RHODOSPOREAE

During the last 15 or 20 years the author has studied the structure of 30 to 40 species of *Pluteus* and 4 or 5 species of *Volvaria*. In all of these species, without a single exception, the trama of the lamellae presents a curious and interesting structure. In the majority of the Agaricaceae, the trama hyphae of the lamellae lie, in general, in a parallel direction, as in *Mycena*, *Tricholoma*, *Collybia*, *Inocybe*, *Entoloma*, *Leptonia*, etc. In *Russula* and *Lactarius* many of the cells are so swollen that the trama of the lamellae presents a vesiculose appearance. In *Amanita* the hyphae show a strong divergence from the median plane toward the subhymenium as they descend in the trama.

In *Pluteus* and *Volvaria*, on the other hand, the most prominent hyphae *converge* as they descend in the trama of the lamellae. Along the median plane of the lamella there can usually be seen, in section, a layer of hyphae (sometimes more slender) against which these prominent cells converge. Attention was called to this peculiar structure in *Pluteus seticeps* in 1902,[2] but no interpretation was offered as to its origin or significance.

During the summer of 1917, Professor LEVA B. WALKER, of the University of Nebraska, while studying the development of *Pluteus*

[2] See *Leptonia seticeps* Atkinson, Jour. Myc. 8:116. 1902. Further collections and studies of this species show that it is a *Pluteus*. While the gills are attached to the stem before the expansion of the plant, they become free, rounded behind, and distant from the stipe. The stipe also easily separates from the pileus, and other structural characters are clearly those of *Pluteus*. It is therefore *Pluteus seticeps* Atkinson, ined.

admirabilis Pk., in this laboratory, discovered the origin of this structure. These prominent hyphae are long, stout, subcylindrical cells, which arise from the inner cells of the subhymenium and extend downward, converging by their free ends against the trama, often compressing it into a thin layer. In some species the free ends of these cells are subcapitate, with a slight constriction below the capitulum. It is clear, therefore, that these peculiar structures in the trama of the lamellae of *Pluteus* and *Volvaria* are internal cystidia of a special kind. They are different in form from the other types of cystidia which project outward beyond the surface of the hymenium in many species. The origin and development of these internal cystidia will be described by Professor WALKER in a forthcoming paper on the development of *Pluteus admirabilis*.

The presence of these numerous internal cystidia, giving a distinct structural aspect to the trama of the lamellae in *Pluteus* and *Volvaria*, indicates that there is a very close phylogenetic relation between these two genera. In both genera the stipe is separable from the pileus, and the spores are of the same type, being smooth, globose, or slightly elongated. No true species of *Annularia* have been examined in the fresh condition to determine whether or not internal cystidia are present. It cannot now be stated with confidence to which group it belongs, but other morphological features indicate that it is more closely allied to *Pluteus* and *Volvaria*. In the other genera of the Rhodosporeae the stipe is not separable from the pileus, the spores are angular, and these peculiar internal cystidia are absent.

In the Rhodosporeae, therefore, there are at least two distinct phyletic lines. The relation of the genera to these two phyletic lines may be represented as follows.

I. PLUTEINAE.—Pileus easily separable from the stipe; lamellae with numerous internal cystidia converging as they descend and sometimes nearly obliterating the trama by pressure; spores smooth. *Pluteus* and *Volvaria* (?*Annularia*).

II. ENTOLOMATINAE.—Pileus not separable from the stipe; lamellae without numerous internal cystidia, trama normal; spores angular. *Entoloma*, *Leptonia*, *Clitopilus*, *Eccilia*, *Nolanea*, and *Claudopus*.—GEO. F. ATKINSON[3]

[3] This paper was received from the late Professor ATKINSON in January 1918.

CURRENT LITERATURE

MINOR NOTICES

British lichens.—The first edition of part first of this work appeared in 1894. The catalogue was done by JAMES M. CROMBIE, who accomplished an excellent piece of work, viewed from the standpoint of the lichenists of his day and the generation preceding him. Part second was to have appeared shortly from the pen of CROMBIE, but his death prevented. Later the task was continued by ANNIE LORRAIN SMITH, and the second part appeared in 1911, following in part the methods of the author of the first part, on which it was an improvement as a whole. In 1918 the revision of part first by Miss SMITH[1] appeared.

The volume contains an introduction dealing with the nature of the lichen and a catalogue of the British lichens (pp. 520). The work of the original author has been thoroughly revised, and the volume contains much new material and marked changes in classification. There are usable keys, and the descriptions have dropped most of the antiquated phraseology of the lichenist of the recent past. They will be more acceptable, therefore, to the botanist of today, who necessarily has been somewhat appalled at the technical language of the lichenist. The 71 plates represent a large amount of work and will be found helpful to the student. Unfortunately, the author's conception of the nature of the lichen is wrong and therefore unfortunate in a work of first rank. In America, at least, and we believe in Europe as well, there has been a marked recent trend of opinion among students of lower plants to the effect that the dual hypothesis regarding lichens is untenable, and that the lichen must be a fungus after all, parasitic on an alga. However, the introduction on the nature of the lichen is a very minor feature of the work, and the publication of this revision gives us from the pen of one person a complete, creditable, and very useful catalogue of the British lichens. Although the catalogue in two volumes deals primarily with the lichens of a limited area, the work will be found useful in the study of the lichens of America and other regions.—BRUCE FINK.

American gall insects.—FELT[2] has published an excellent and usable key to the American gall insects. It is arranged with reference to the host plants on which the galls occur and will be of great value to every botanist who has

[1] SMITH, ANNIE LORRAIN, A monograph of the British lichens. Vol. I. 8vo. pp. xxiv+520. *pls. 71. figs. 11.* The British Museum. 1918.

[2] FELT, E. P., Key to American gall insects. N.Y. State Museum Bull. 200. pp. 310. *pls. 16.* 1917.

occasion to collect and determine plants or to study abnormal plant growths. It is the only reasonably complete publication of the kind in America. There are a total of 1439 species, most of which can very readily be recognized by means of the key, the 250 text illustrations, and the 16 full page plates. The publication is indexed both with reference to the host and the parasite.—MEL. T. COOK.

North American Flora.—The sixth part of volume 22 contains the conclusion of Rosaceae by RYDBERG, including genera 54 to 57, much the largest genus being *Rosa*, with 129 species, 23 of which are described as new. The part closes with 26 pages of additions and corrections to the volume.

The first part of volume 32 contains the beginning of Rubiales by STANDLEY, 8 genera of the Rubiaceae being presented. Much the largest genus is *Rondeletia*, with 109 species, 8 of which are described as new. Among the remaining genera 8 new species are described.—J. M. C.

NOTES FOR STUDENTS

Secondary dormancy in seeds.—KIDD and WEST[3] have continued the study of the controlling action of carbon dioxide on the germination of seeds of *Brassica alba*. In two previous papers by the senior author it has been shown that low concentrations of carbon dioxide inhibit the germination of seeds, and that temperature and oxygen pressure determine the concentration necessary to inhibit germination. In normal oxygen pressure 2–4 per cent carbon dioxide will inhibit germination at 3° C., while at 20° C. it requires 20–25 per cent. At 17° C. it requires 9–12 per cent carbon dioxide to inhibit with 5 per cent oxygen pressure and 20–25 per cent carbon dioxide with 20 per cent oxygen pressure. All seeds studied, except *Brassica alba*, germinate normally as soon as the carbon dioxide is removed, while *B. alba* remains dormant after the carbon dioxide is removed. The authors term this "secondary dormancy," in agreement with the usage of this term by CROCKER.

In the production of secondary dormancy the authors note the following general facts: (1) secondary dormancy is not produced if oxygen is absent during the primary period of inhibition or if carbon dioxide has been used in too high concentration; (2) conditions during the primary period of inhibition which prevent subsequent occurrence of dormancy are the ones that exercise injury on the radicle; (3) 100 per cent dormancy is obtained only within narrow limits of carbon dioxide and oxygen pressure. Secondary dormancy is not produced by a change in the permeability of the coats to gases or water, or to an increase in their breaking strength, but by a change in the embryo

[3] KIDD, F., and WEST, C., The controlling influence of carbon dioxide. The production of secondary dormancy in seeds of *Brassica alba* following treatment with carbon dioxide and the relation of this phenomenon to the question of stimuli in growth phenomena. Ann. Botany **31**:457–487. 1917.

by which it becomes less responsive to germinative conditions. The following conditions caused the secondarily dormant seeds to germinate: removal or partial removal of the testa; redrying of the soaked seeds; short exposures to high or low temperatures; treatment with acids (especially n o.01 HCl and propionic); treatment with high concentrations of carbon dioxide followed by germination in air. High partial pressures of oxygen had no effect on the germination of secondarily dormant seeds.

The authors give the following interpretation of this work: "It will be seen that the main interest of this communication centers around the causes underlying the initiation of growth rather than in the conditions of dormancy. In considering this question of growth in the case of seeds of *B. alba*, our experiments show clearly that there is no question of limiting factors. We have been able to trace no limiting factor responsible for the non-germination of white mustard seeds showing secondary dormancy. We find ourselves rather in the presence of facts which emphasize a conception of stimulus. It has been seen that widely different treatments, quite unclassifiable in any feature other than that they all result in injury and death, if carried too far, excite germination and growth of white mustard seed. It appears to us probable that some return will have to be made to this conception of stimulus in plant physiology generally, and that in any experimental analysis of the living plant, as a unit and in relation to its life-cycle, the idea of limiting factors, which has so long dominated the minds of plant physiologists, will have to be modified."—Wm. Crocker.

Chondriosomes in plants.—Investigations dealing with chondriosomes have become so numerous that it seems worth while to make a brief summary of the results obtained. As might be expected, a few structures of different nature have been called by the same name; but a host of names have been applied to the same structure, so that we have mitochondria, chondriosomes, chondriomites, chondriokonts, chromidia, sphaeroblasts, histomeres, plasmosomes, cytomicrosomes, etc. The "chondr," meaning a small grain, was chosen because most of the bodies are in the form of small granules; the "mito," meaning thread, is often suggestive, because the granules have a tendency to become arranged in rows. The terms mitochondria and chondriosomes will probably survive, and if a choice should be made between these two, it should be the latter, since it is noncommittal; while the fact that the threadlike arrangement is by no means universal is an objection to the term mitochondria. The name chromidia was applied because the writer believed that the granules were portions of the chromatin extruded from the nucleus. Such granules certainly occur in animals and possibly in plants, but they are not the same structures as the chondriosomes.

A historical résumé of the subject, with a very complete bibliography up to 1914, was compiled by Cavers,[4] and in an investigation upon the rela-

[4] Cavers, F., Chondriosomes (mitochondria) and their significance. New Phytol. 31:170–180. 1914.

tion between chondriosomes and plastids, MOTTIER[5] has brought the literature up to 1918.

LA VALETTE ST. GEORGE, working upon the male cells of insects, gave the first description of chondriosomes. He introduced the term cytomicrosomes. MEVES, in 1904, gave the first description for plants, using the tapetal cells of anthers of *Nymphaea* for material. LEWITSKI, in 1910, was first to claim that chondriosomes give rise to plastids. A little later he made a comparative study upon living and fixed material, showing conclusively that the bodies are present in living cells. The investigation by MOTTIER, to which reference has already been made, proves that some chondriosomes give rise to chloroplasts and leucoplasts. He also believes that the chondriosomes are permanent organs of the cell, of equal rank with the nucleus. Of course he recognizes that chloroplasts and leucoplasts also multiply by division. His claim that chondriosomes are concerned in the transmission of hereditary characters does not seem to be so well supported. Some investigators have suggested that chondriosomes transmit characters of the cytoplasm and that the chromosomes transmit characters of the nucleus.

It seems to be established that chondriosomes are not artifacts, that they multiply by division, and that some of them give rise to plastids. Their rôle in heredity, if they have any, still remains to be demonstrated.—C. J. CHAMBERLAIN.

Trimorphism of Pontederia.—The family Pontederiaceae is notable as containing the only known heterostyled species among monocotyledons (with possibly one exception), and is further remarkable among heterostyled plants as furnishing the only recorded examples of distinctly zygomorphic flowers in such plants. HAZEN[6] has recently published interesting observations on *Pontederia cordata* L. LEGGETT had reported in 1875 that this species was trimorphic, and the present paper is a detailed study of the flower forms, pollination, insect visitors, etc.

The tubular perianth is slightly zygomorphic and in all 3 flower forms presents 2 sets of stamens: a longer set of 3 on the anterior side of the flower, and 3 short-stalked stamens on the posterior side of the flower. In 2 of the flowers the upper stamens protrude beyond the open perianth. The long-styled stigma reaches a height of 12–13.5 mm., the mid-styled form 7–8 mm., and the short-styled form 3–3.5 mm. above the base of the ovary. The ratios of the average heights of the 3 lengths of pistils are approximately as 100, 60, and 22.

While the arrangement of parts is different in each of the 3 flower forms, it results in 2 sets of stamens adjusted to each length of pistil. The 6 legitimate crosses which may take place between the 6 sets of stamens and the 3 different

[5] MOTTIER, D. M., Chondriosomes and the primordia of chloroplasts and leucoplasts. Ann. Botany **32**:191–214. *pl. 1.* 1918.

[6] HAZEN, TRACY E., The trimorphism and insect visitors of *Pontederia*. Mem. Torr. Bot. Club **17**:459–484. 1918.

pistils are such that each flower type may be pollinated by either of the other 2 flower forms. Moreover, the flowers are placed on the axis of the spike so nearly horizontal as to lessen the probability of self-pollination.

The microspores are ellipsoidal in form and the different sets of stamens show marked differences in size of pollen grains, the higher anthers having the larger pollen, the middle ones intermediate, and the short-stalked stamens the smallest spores. This relation suggests a correspondence with the 3 types of stigmas. Averaging a large number of spores it was found that the mean diameters of the 3 sizes of pollen grains were as 100, 80, and 51, and their volumes respectively as 100, 53, and 14. Recalling HALSTED'S work on *Eichhornia crassipes*, in which he found that all sizes of pollen grains germinated if given sufficient time, but that the larger spores germinated much more promptly than the smaller, HAZEN suggests that prompt germination would be of great advantage in the long-styled *Pontederia* flowers in which the flowers wither so quickly that a slow germinating spore might not have time to function.

The author lists observed insect visitors, naming 10 Lepidoptera and 4 Hymenoptera, the least skipper, *Ancyloxypha numitor* Fabr., being the most frequent visitor. Experimental work by the author is in progress on the relative fertility of the different flowers with various pollen combinations, and its publication is awaited with interest.—R. B. WYLIE.

Phototropism.—Miss PARR,[7] working in HOTTES' laboratory of the University of Illinois, has done an excellent piece of quantitative work on the response of *Pilobolus* to light. The literature on phototropism has been full of conflicting statements and theories, very largely due to the lack of quantitative work of the type done by Miss PARR. This work does much to show the reasons for these diverse views and to lay the foundations for substantial progress. The physics department of the University assisted in the control of the delicate instruments used in the measurements of light. It is very desirable at this stage of plant physiology that we get the more general cooperation of well-trained physicists and chemists to aid in transforming plant physiology from a qualitative to a quantitative science. The results of the work can best be presented by quoting the summary: (1) *Pilobolus* responds to the light of all regions of the visible spectrum; (2) the presentation time decreases gradually from red to violet, and there is no indication of intermediate maxima and minima; (3) the presentation time does not vary in direct ratio with the measured value of the energy of the light in the different regions of the spectrum; (4) the presentation time varies in inverse ratio to the square roots of the wave-frequency; (5) the product of the square root of the frequency times the presentation time decreases with the decrease in the energy value of the spectral regions and is an approximate constant for a given light source; (6) the spectral energy in its relation to presentation time may be expressed approximately in

[7] PARR, ROSALIE, Response of *Pilobolus* to light. Ann. Botany 32:177–205. 1918.

the Weber-Fechner formula, if the wave-frequencies be made a function of the constant; (7) the relation of the spectral energy to the presentation time may also be approximately expressed in the Tröndle formula, the wave-frequency being made a function of the constant.—WM. CROCKER.

Breeding for disease resistance.—It has been a popular impression that newly produced disease resistant varieties will gradually lose their immunity in later generations. The idea was that such new varieties might sometimes become slightly infected; this short sojourn of the disease organism in the normally immune host would enable the former to adapt itself to the new conditions and gradually acquire virulence, until finally a new biologic form was developed to which the host in question was quite susceptible. EVANS[8] carried the same idea further when he found that a cross between resistant and susceptible races of wheat produced a hybrid even more susceptible to rust than the susceptible parent. Furthermore, rust from the hybrid could now infect the immune parent. Such facts were very discouraging, since they indicated that the artificial breeding of resistant crop plants is rapidly overtaken by the natural breeding of new biologic forms of the disease organism.

Particularly acceptable, therefore, is the work of STAKMAN, PARKER, and PIEMEISEL,[9] who find that wheats resistant to rust remain resistant regardless of the previous history of the rust; the gap between immune and susceptible varieties is not bridged by transitional varieties or by artificial hybrids. "Resistance is rather an hereditary character, which cannot be produced by the accumulation of fluctuating variations within a susceptible line, nor broken down by changes in the host or parasite." Acceptable as such a conclusion may be, both to commercial breeders and to academic geneticists, it is very questionable how widely it may be applied. It will be difficult, although not hopeless, to explain away much of the contrary evidence.—MERLE C. COULTER.

Nature of monocotyledonous leaves.—Mrs. ARBER[10] has presented the results of an anatomical investigation of the phyllode theory of the monocotyledonous leaf. According to DECANDOLLE, it is equivalent to the leaf-base and petiole of a dicotyledonous leaf, but Mrs. ARBER believes that certain monocotyledonous leaves are still further reduced in that they are equivalent to leaf-bases only. In case the monocotyledonous leaf shows a distinction of petiole and blade, HENSLOW suggested that the blade is merely an expansion

[8] EVANS, I. B. P., South African cereal rusts, with observations on the problem of breeding rust resistant wheats. Jour. Agric. Sci. 4:95–104. 1911.

[9] STAKMAN, E. C., PARKER, JOHN H., and PIEMEISEL, F. J., Can biologic forms of stem rust on wheat change rapidly enough to interfere with breeding for rust resistance? Jour. Agric. Research 14:111–123. *pls. 13–17.* 1918.

[10] ARBER, AGNES, The phyllode theory of the monocotyledonous leaf, with special reference to anatomical evidence. Ann. Botany 32:465–501. *figs. 32.* 1918.

of the apical region of the phyllode and not homologous with the blade of a dicotyledonous leaf. Such a blade among monocotyledons Mrs. ARBER calls a "pseudo-lamina." Such theories have been devised to explain the parallel venation of monocotyledonous leaves. Attention is also called to GRAY's suggestion that some gymnosperm leaves may be equivalent to petioles, and the further suggestion made that this may be applied specially to the Gnetales.

These views were tested by Mrs. ARBER in anatomical investigations, comparing scale-leaves, petioles, and phyllodes of dicotyledons with the leaves of monocotyledons, the conclusion being reached that the occurrence of inverted vascular bundles toward the adaxial face of a leaf may be an indication of "phyllodic morphology." Other indications of phyllodic anatomy are developed, and its systematic distribution shows that it does not occur with any frequency outside the Helobiae, Liliiflorae, and Farinosae. This distribution is taken to confirm the view that phyllodic anatomy is an ancient character, revealing the origin of the monocotyledonous leaf.—J. M. C.

Stomata.—REHFOUS[11] has published a detailed study of the stomata of many groups. The details are too numerous for citation, but some of the general conclusions may be indicated. He is convinced that stomata are of first importance in indicating phylogeny and relationships. Their structure he claims is very constant within a group, numerous examples of this being given. For example, the structure of the stomata of the Amentiferae shows that they are nearer the level of the dicotyledons than of the gymnosperms or pteridophytes. In the same way it is shown that the Polypodiaceae constitute a special group, and that the Osmundaceae, Gleicheniaceae, and Schizeaceae approach more nearly the higher plants. A close resemblance is found between the stomata of cycads and conifers, leading to the conclusion that these groups are of common origin. Numerous illustrations of claimed relationships within great groups are either confirmed or contradicted. Several new types of stomata are described, among which those of *Polypodium*, *Platycerium*, *Cycas*, and *Casuarina* may be cited. In connection with the last named genus it is pointed out that its stomata are related to those of certain monocytoledons, as the grasses and certain of the xerophytic Liliaceae. The contribution is a valuable assemblage of facts in reference to the structure of stomata, accompanied by clear illustrations. The conclusions drawn from these facts are open to discussion.—J. M. C.

Water conduction in trees and shrubs.—FARMER[12] has published the results of an investigation of the comparative efficiency of the wood as a water-conducting tissue in about 60 species of plants, chiefly trees and shrubs. The

[11] REHFOUS, LAURENT, Étude sur les stomates. Univ. Genève, Inst. Bot. IX. no. 6. pp. 110. *figs. 125.* 1917.

[12] FARMER, J. BRETLAND, On the quantitative differences in the water-conductivity of the wood in trees and shrubs. Proc. Roy. Soc. B. **90**:218–250. 1918.

intake of water by the roots and its transpiration from the leaves have been much investigated, but "the behavior of the wood as the intervening conducting channel has almost entirely been neglected." The method used was to measure the amount of water passing in a given time and at standard pressure through a definite length of twig, the area of the cross-section of the wood being carefully measured. The paper includes two parts, one dealing with evergreens and the other with deciduous plants.

Some of the results are as follows. The specific conductivity of evergreens is relatively low, while that of deciduous plants is relatively high, and with a higher fluctuation. Some of the deciduous trees are more influenced by environmental conditions than are others. Considerable difference, in a lowering of conductivity, was found between the adult wood of the tree and that of "leaders" of young trees, a difference which becomes "exaggerated" in the main shoot of most climbers. The wood of arborescent monocotyledons was found to be defective in water-conductivity. The facts suggest that the lower conductivity of evergreens may be attributed to their narrow and short vessels.—J. M. C.

The Journal of General Physiology.—Many will welcome a new journal of general physiology.[13] Both plant and animal physiology have suffered from being too little related and treated as distinct subjects. Such a publication will aid in bringing them into closer relation. This journal is sure of sufficient financial support and no doubt able editorship. Its aim is stated as follows: "*The Journal of General Physiology* is devoted to the explanation of life phenomena on the basis of the physical and chemical constitution of living matter." The first number contains the following articles: On the dynamics of photosynthesis, W. J. V. OSTERHOUT and A. R. C. HAAS; A method of studying respiration, W. J. V. OSTERHOUT; The antagonism between thyroid and parethyroid glands, E. UHLENHUTH; Difference in the action of radium on green plants in the presence and absence of light, C. PACKARD; Amphoteric colloids, J. LOEB; A theory of the mechanism of disinfection, hemolysis, and similar processes, S. C. BROOKS; The law controlling the quantity of regeneration of the stem of *Bryophyllum calycinum*, J. LOEB; Reversal of reaction by means of strychnine in planarians and starfish, H. R. MOORE; Light and the muscle tonus of insects; the heliotropic mechanism, W. E. GARREY; Lutear cells and hen-feathering, ALICE M. BORING and T. H. MORGAN.—WM. CROCKER.

Embryo sac and fertilization in Oenothera.—ISHIKAWA[14] has investigated the behavior of the gametophytes and the fertilization phenomena in *O. nutans*

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[13] The Journal of General Physiology, editors, JACQUES LOEB and W. J. V. OSTERHOUT. Published bimonthly by the Rockefeller Institute for Medical Research. Vol. I. No. 1. September 1918. Subscription $5.00.

[14] ISHIKAWA, M., Studies on the embryo sac and fertilization in *Oenothera*. Ann. Botany 32:279–317. *pl. 7. figs. 14.* 1918.

and *O. pycnocarpa* and their hybrids, both of which species were formerly included in *O. biennis*. Many valuable confirmatory details need not be cited, but the following may be mentioned. The embryo sac is 4-nucleate, lacking antipodals and one of the polar nuclei, and this condition was found not only in *Oenothera*, but also in *Ludwigia*, *Gaura*, *Godetia*, and *Circaea*. The author regards it as a diagnostic character of Onagraceae, and therefore would exclude *Trapa*, with its normal 8-nucleate sac, from the family. This condition in Onagraceae he thinks may have been produced by mutation, but not by adaptation. The pollen tube enters the synergid and the "mixed plasma" flows out and spreads over the egg. The cytoplasm of the pollen grain was found to contain an immense number of minute starch grains, which migrate through the pollen tube, enter the synergid, and finally disappear. The male nucleus is inclosed in a distinct plasma sheath until it reaches the egg. The synergid and the upper two-thirds of the egg have a distinct cellulose membrane, the lower part of the egg acquiring it after fertilization. Self-sterility of some hybrids is said to be due to the feeble growth of the pollen tube.—J. M. C.

Histology of phloem.—There has been a tendency in recent years to assume that the doctrine of recapitulation is a law as valid and invariable as the laws of physics and chemistry, and to use it as a reliable short cut in the study of the evolution of plants. However, it is to be emphasized that a law is a statement of fact, not a theory or working hypothesis. If the doctrine of recapitulation and similar generalizations are to be accepted as true laws they must be capable of statistical or experimental proof. MACDANIELS[15] points out that, although in a considerable number of woody dicotyls which he studied there is no fundamental difference between the type of sieve tube found in seedlings and first annual rings and that found in the mature condition, the remaining forms possess a presumably less primitive type of structure in the earlier than the later stages of ontogeny. Furthermore, he shows that there is no close parallelism in the specialization of sieve tubes, vessels, and floral structures. It has been a common morphological fallacy to assume that because the evolution of a selected structure progresses apparently in a given direction the sums of all structures (organisms) are moving in a similar direction. MACDANIELS' comprehensive and painstaking piece of work is a valuable contribution to our knowledge of the histology of phloem.—I. W. BAILEY.

Enzyme secretion.—The influence of such inorganic salts as the nitrates, chloride sulphates, and monobasic phosphates of sodium and potassium, and the chlorides and sulphates of calcium and magnesium on the secretion of diastase by *Penicillium camembertii* has been investigated by ROBBINS.[16]

[15] MACDANIELS, L. H., The histology of the phloem in certain woody angiosperms. Am. Jour. Bot. 5:347–378. 1918.

[16] ROBBINS, W. J., Influence of certain salts and nutrient solutions on the secretion of diastase by *Penicillium camembertii*. Amer. Jour. Bot. 3:234–260. 1916.

The general results show decrease in the amount of digestion of starch by the fungus in the presence of low concentrations (M/10,000 and M/100,000) of the chlorides and sulphates. The view is taken that the decreased digestion is caused by decreased secretion of diastase rather than by inhibition of the activity of secreted diastase. Potassium salts decrease secretion more than corresponding sodium salts. Experiments with nutrient solutions instead of single salts showed the same general effect, decreased secretion. No evidence was found to support the idea that calcium or potassium is intimately related to diastase formation. On the other hand, nitrogen may possibly have some relation to enzyme formation. Nitrates added singly increase the actual amount of starch digestion, but since the mycelial growth is much increased, there is really less digestion per unit of dry weight of mycelium.—C. A. SHULL.

Reaction of the medium and nitrogen assimilating organisms.—FRED and DAVENPORT[17] have studied the relation of the legume bacteria and *Azobacter* to low concentrations of acids and alkalies. When sulphuric acid was added to the nutrient solutions, the following hydrogen ion concentrations were found to be critical for the various legume organisms: alfalfa and sweet clover, P_H 4.9; garden pea, field pea, and vetch, P_H 4.7; red clover and common beans, P_H 4.2; soy beans and velvet beans, P_H 3.3; lupines, P_H 3.15. The authors believe a correlation exists between the acid resistance of the bacteria and the acid resistance of the higher plant with which they are associated. These organisms are not injured by normal alkali additions to the culture medium until the addition is about 10 times that of sulphuric acid producing injury. There seems to be little difference in the several strains as to the alkali resistance.

Azobacter is limited to a much narrower range of reaction than are the legume organisms, the critical limits being 6.5 P_H for acid and 8.6 P_H for alkali. It is to be regretted that the reaction was not determined by the gas chain as well as by the colorimetric method.—WM. CROCKER.

Transpiration.—DUGGAR and BONNS[18] have issued a third paper from the Missouri Botanical Garden on the effect of a film of Bordeaux mixture and other films on the transpiration of leaves. In potted mesophytes such a film increases generally the transpiration at night, but has less or no effect during the day. Similar behavior is shown by excised leaves. In *Cyperus esculentus*, a plant of xerophytic surface modification, such films have no effect on transpiration rate. The writers offer as tentative the following explanation: the film of Bordeaux mixture on the surface of a plant in a state of guttation acts more or less as a bibulous surface, taking water directly from the interior of the plant, through at least some continuous water channels

[17] FRED, E. B., and DAVENPORT, AUDREY, Influence of reaction on nitrogen-assimilating bacteria. Jour. Agric. Research 14:317–336. 1918.

[18] DUGGAR, B. M., and BONNS, W. W., The effect of Bordeaux mixture on the rate of transpiration. Ann. Mo. Bot. Gard. 5:153–176. 1918.

established by means of the open water-suffused stomata. This would account for the effectiveness of the film at night and for its lack of effectiveness with *Cyperus* with its very narrow stomata. The authors state that there are difficulties in the incipient guttation explanation as applied to excised leaves.—WM. CROCKER.

Turgor movements.—BLACKMAN and PAINE,[19] by use of a special conductivity cell, have studied the conductivity of the liquid extruded from the lower half of the excised pulvinus of *Mimosa pudica* due to the shock stimulus. The shock response gives an increase in conductivity, but not nearly enough to attribute the contraction to increased extrusion of solutes. They believe, therefore, that the contraction is due to a sudden condensation of solutes within the pulvinal cells of the lower half of the pulvinus. They consider the conductivity method far superior to the plasmolytic method used by previous authors, for it answers directly the amount of movement of solutes. Under certain conditions they get autonomic movements of this organ similar to those of the leaflets of *Desmodium gyrans*. A slow rise of temperature up to 50° C. shows little increase in exosmose of electrolytes from this organ. The increase of permeability at higher temperatures seems to be due to lethal irreversible changes.—WM. CROCKER.

Alternation of generations in Padina.—*Padina variegata*, one of the Dictyotaceae, is abundant at Beaufort, North Carolina, where it has been studied by WOLFE.[20] Sperms, eggs, and tetraspores are borne on 3 separate plants which look alike in the vegetative condition, but which are easily recognized during reproduction. Tetraspores give rise to only male and female plants in approximately equal numbers, so that sex is probably predetermined during the reduction division in the tetraspore mother cell. Fertilized eggs produce only tetrasporic plants, so that there is an alternation of sporophyte and gametophyte generations. Eggs often germinate without fertilization, but plants of such parthenogenetic origin do not mature. It would be interesting to know the chromosome numbers, especially in the parthenogenetic plants, and we hope that WOLFE, who is familiar with the cytological technique of the algae, will investigate this phase of the problem.—C. J. CHAMBERLAIN.

The luminous moss.—TODA[21] has made a physiological study of *Schistostega osmundacea*, the so-called luminous moss, his material having been obtained from a cave in Japan. He found the optimum intensity of light as well as the minimum and maximum intensities in terms of Bunsen's unit. In a dark place

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[19] BLACKMAN, V. H., and PAINE, S. G., Studies in the permeability of the pulvinus of *Mimosa pudica*. Ann. Botany **32**:69–85. 1918.

[20] WOLFE, J. J., Alternation and parthenogenesis in *Padina*. Jour. Elisha Mitchell Scientific Soc. **34**:78–109. 1918.

[21] TODA, VISCOUNT YASUMOCHI, Physiological studies on *Schistostega osmundacea* (Dicks) Mohr. Jour. Coll. Sci. Tokyo **40**:no. 5. pp. 30. *pls.* 2. 1918.

the protonema can live for 7 months without producing a leafy shoot. He observed also the movement of "chomatophores," which became scattered in a day when the protonema is placed in light, and when the direction of light is changed they all turn toward it in 7–10 days. Blue and violet light proved to be more favorable than any other of the visible rays, excepting of course white light. The optimum temperature for the development of the leafy shoot is 16–25° C.; the protonema does not die so long as the temperature is above −20.5° C., but the leafy shoot dies at −18° C. The spore at a temperature of 16–25° C. germinates in one month.—J. M. C.

Angiosperm wood lacking vessels.—BAILEY and THOMPSON,[22] in continuing their work on certain genera of angiosperms in which true vessels are absent from the normal wood of the stem, have obtained additional evidence. Their attention had been called to the occurrence of vessel-like structures in injured roots of a species of *Drimys*, which might indicate that the ancestors of the 3 genera investigated possessed true vessels. An examination of these structures has led to the conclusion that they are not vessel-like in structure, but are typical tracheids, which occur as well in uninjured stems of the 3 genera. They maintain, therefore, that true vessels do not occur in the xylem of these genera, and that there is no evidence that their ancestors possessed true vessels.—J. M. C.

Permeability.—PAINE and SAUNDERS[23] find that the testa of the pea is impervious to various reagents dissolved in water (copper ferrocyanid, sodium chloride, safranin) due to a waxy bloom deposited on the outer surface. This bloom is easily rubbed off so that the testa becomes pervious. In the wrinkled peas the bloom rubs off on the wrinkles, leaving the depressions still impervious, while in the smooth pea the bloom rubs off uniformly on the whole surface. It is interesting to find such a superficial layer responsible for the peculiar permeability characters of seed coats, for these characters are generally determined by deeper layers.—WM. CROCKER.

Agaricaceae of Michigan.—KAUFFMAN,[24] in connection with his very full presentation of the Agaricaceae of Michigan, has monographed *Russula* (pp. 118–167), *Pholiota* (pp. 289–314), and *Cortinarius* (pp. 314–442), as represented in the state. In *Russula* he recognizes 53 species, 3 being new and 27 edible; in *Pholiota* 26 species, 4 of which are edible; in *Cortinarius* 154 species, 13 of which are new and 10 edible. As an illustration of the activity of CHARLES

[22] BAILEY, I. W., and THOMPSON, W. P., Additional notes upon the angiosperms *Tetracentron*, *Trochodendron*, and *Drimys*, in which vessels are absent from the wood. Ann. Botany 32:503–512. *pl. 16. figs. 9.* 1918.

[23] PAINE, S. G., and SAUNDERS, L. M., On a peculiarity exhibited by the testa of wrinkled peas. Ann. Botany 32:175. 1918.

[24] KAUFFMAN, C. H., The Agaricaceae of Michigan. Mich. Geol. and Biol. Survey, Publ. 26. Biol. Series 5. December 1918.

PECK in these groups it is interesting to note that he is credited with 16 species in *Russula*, 11 in *Pholiota*, and 62 in *Cortinarius*, and this has to do only with Michigan species.—J. M. C.

Seedling anatomy.—HOLDEN and BEXON[25] have begun a series of studies on the anatomy of teratological seedlings. The first paper deals with seedlings of *Cheiranthus Cheiri*, which showed "cotyledonary abnormality ranging from hemitricotyly to tetracotyly." The conclusion was reached that there are at least two methods of cotyledonary increase, cotyledonary fission and dichotomy of the growing point of the cotyledon. A third method is somewhat doubtfully suggested, namely "the downward displacement of one or more epicotyledonary leaves."—J. M. C.

Apogamy in Camptosorus.—Mrs. BROWN[26] has described a case of apogamy in *C. rhizophyllus* that occurred in cultures to determine if apogamy could be induced by the modification of external conditions. The apogamous outgrowth was in general a cylindrical process, with some interesting details as to shape and structure, in which a cluster of tracheids appeared. Previous experimental work had indicated that bright light and relative dryness were the factors involved; but in this case low nutrition seemed to be more important than either.—J. M. C.

Tropical species of Eupatorium.—ROBINSON[27] has published the results of a study of *Eupatorium* as displayed in the American tropics. The wealth of species illustrates how much of the flora of the world remains to be discovered. There are 39 new species described, in addition to new varieties. He has included also a revision of the Colombian species, recognizing 93 species distributed among 7 sections. "Keyed recensions" are given also of the species of Venezuela (35) and of Ecuador (50).—J. M. C.

The orchids of Java.—SMITH,[28] in a fifth paper on the orchids of Java, continues to bring to light the remarkably rich orchid flora of that island. He discusses 61 species representing 27 genera, including 38 new species and 2 new genera (*Chroniochilus* and *Saccolabiopsis*).—J. M. C.

A new genus of Compositae.—PRITZEL[29] has published a new genus (*Basedowia*) of Compositae from Australia. It resembles *Helichrysum*, as the name (*B. helichrysoides*) suggests. The genus is named for HERBERT BASEDOW, state geologist of South Australia.—J. M. C.

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[25] HOLDEN, H. S., and BEXON, DOROTHY, Observations on the anatomy of teratological seedlings. I. On the anatomy of some polycotylous seedlings of *Cheiranthus Cheiri*. Ann. Botany **32**:513–530. *figs. 17*. 1918.

[26] BROWN, ELIZABETH DOROTHY WUIST, Apogamy in *Camptosorus rhizophyllus*. Bull. Torr. Bot. Club **46**:27–30. *pl. 2*. 1919.

[27] ROBINSON, B. L., Contrib. Gray Herb. Proc. Amer. Acad. **54**:235–367. 1918.

[28] SMITH, J. J., Die Orchideen von Java. Bull. Jard. Bot. Buitenzorg II. no. 26. pp. 135. 1918.

[29] PRITZEL, E., *Basedowia*, eine neue Gattung der Compositen aus Zentral-Australien. Ber. Deutsch. Bot. Gesell. **36**:332–337. *pl. 12*. 1918.